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THE JOINT MEASURING CAMPAIGN 1979

IN RUTHE (WEST GERMANY)

DESCRIPTION AND PRELIMINARY DATA.

Editors: R.R. van der Ploeg, G. Tassone and J. von Hoyningen-Huene

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FOREWORD

During June 1979 a Joint Measuring Campaign devised and financially supported by the Joint Research Centre of the European Communities, Ispra Establishment, was held at Ruthe (West Germany). The Campaign was part of a project (TELLUS Project), carried out by the Joint Research Centre, on soil moisture and heat budget evaluations in selected European zones of agricultural and environmental interest with use of remote sensing techniques. The TELLUS Project in turn is part of work sponsored by the National Aeronautics and Space Administration (NASA) to test the feasibility of measuring the earth's surface temperature for environmental studies with a research satellite, called the Heat Capacity Mapping Mission (HCMM).

The present notes are intended to inform the people cooperating in the TELLUS Project about the measurements and observations taken during the Campaign.

No final results are presented here. They will be published elsewhere at a later date once the data processing and interpretation are finished.

The Commission of the European Communities, the Directors of the Institutes partecipating to the Campaign, Drs. F. Geiss (J.R.C., Ispra) and R. Feddes (ICW, Holland) and all who contributed and supported this campaign are acknowledged.

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1. The TELLUS Project

S. Galli de Paratesi, G. Tassone, F. Toselli

Joint Research Center of the European Communities,
Ispra Establishment, Ispra

Following the decision of the Commission of the European Communities to participate into NASA's Heat Capacity Mapping Mission (HCMM), the Joint Research Center, Ispra set-up the TELLUS Project whose main objective is the application to agriculture and environment of the day and night temperatures measured by the HCMM satellite and/or aircrafts /1/.

The Project was organized in such a way to permit:

a)- the concentration of diversified competences

b)- the setting-up, organization and support of the research of several European Institutes (Co-investigators)

c)- the promotion of Remote Sensing activities in the European countries, always fulfilling the specific needs of EC's policy and taking also into account the interest of the participating Institutes as for their agricultural and environmental research activity.

2. Framework of Coinvestigators

The Co-Investigators are divided into six groups:

EC Directorate-General and JRC (Ispra Establishment)
Benelux Institutes
British Institutes
French Institutes
German Institutes
Italian Institutes

3. Test Sites

The TELLUS test-sites are reported in Table 1. Geographic considerations as well as technical and efficiency reasons led to regroupe them in 5 groups according to the Institutes involved and to designate for each group one Co-Investigator as Test-site Coordinator.

Test Site Group/Country	Test Site	No.
ITALY	Puglia Sardegna Emilia	1 2 3
FRANCE	Bouches du Rhône Bretagne	4 13
GERMANY	Rhine Valley 1 Rhine Valley 2 Northern Alps Northern Germany	5 6 7 15
UNITED KINGDOM	Basilicata (Italy) England 1 Wales England 2 England 3	1 8 9 10 11
BENELUX	Benelux	12

Table 1. TELLUS Test-sites, arranged in groups.

Table 1.1

Fig.1 shows the spatial distribution of the TELLUS test sites within the European coverage area of the HCMM receiving stations of MADRID (NASA) and LANNION (ESA). The "diamond" on the right hand of Fig.1.1encloses twelve-hour night/day coverage pattern due to the intersection of the corresponding satellite orbites.

4. Main Lines of Investigation

According to the interest of the EC's Commission and the proposals made by the national Institutes, three main research subjects have been singled out:/2/

1. Evapotranspiration and moisture content in bare soils covered by vegetation.
   Evapotranspiration and soil moisture are by far the most important parameters in agricultural management because of their impact on planning of water supply, irrigation, cultivation choice and on occurence of flooding, erosion, ecc.
2. Interactions between natural phenomena and mesoscale heat budget.
3. Man-made changes and their impact on regional heat budget.
   The heat budget is a relevant environmental parameter for its influence on vegetation and man. Variation in regional heat budget can be due both to natural and man-made causes. Its overall evaluation on a regional scale, especially where mixed rural and industrial activities are present, is very important to the conservation of environmental quality and the planning of human activities.

5. Evapotranspiration and Soil Moisture

These two items constitute the main research line of the TELLUS Project.

5.1 The approach adopted

A two days approach has been adopted:

a) Visual interpretation of the HCMM-images (originals or transformed).

The method may be defined as an analog-deductive interpretation procedure, final products being hydro-geological maps.

Instrumentation employed consists of stereo-plotters, densitometers, analog image-analyzers and additive color-viewers- [3]

b) Models for evaluation of evapotranspiration and soil moisture.

Digital models whose parameters are obtained from air-and-space platforms (aircraft and/or HCMM satellite) and ground-based instrumentation allow the evaluation of evapotranspiration and soil moisture content. Energy balance on the soil surface and the atmospheric boundary layer is applied. Such models are written in a form that most of the input data used are routinely observed and adapted so that remotely-sensed measurements can be included (4,5)

Final products are thematic maps (evapotranspiration, thermal inertia, soil moisture, etc.) (6,7).

It is felt that this approach allows to gain deeper understanding of the processes relating evapotranspiration and soil moisture with meteorological and ground parameters and the remotely sensed temperatures and albedo.

Moreover, it can provide scientific basis for empirical correlations between the above parameters simplifying the algorithms.

Sensitivity analysis of the models were performed first and then testing was done for a number of field conditions. In this way the validity of the models was checked and the importance of the various parameters verified.

7. The Joint Measuring Campaigns (JEMC)

Following the above lines of research the European Communities launched, financed and coordinated through the Joint Research Center of Ispra the following campaigns:

Aircraft Flights:

- September 1977 - UK (Grendon and Newbury)
- September 1977 - France (Beauce)
- July 1978 - Italy (Sibari-Calabria)

Long term campaigns:

- July 13 - September 6, 1977 - Città di Castello (Italy)
- May 23 - July 16, 1978 - Policoro (Italy)
- April 15 - May 16, 1979 - Policoro (Italy)

All these experiments were made with the participation of research teams of the JRC and Institutes of the host countries. They were directed to preliminary testing and setting up of two evapotranspiration and moisture models (bare soil and soil covered by vegetation) They were performed on test lands composed by homogeneous patches having area far below that required by the HCMM resolution (0,6 km x 0,6 km). This was due to the rather fragmented agricultural land structure.

Moreover, geometrical considerations pointed out that in order to get reliable information from the Heat Capacity Mission Radiometer (HCMR) the surfaces investigated should have at least an homogeneous expanse of 4-5 satellite pixels. Due to the nature and use of European rural land (rather small fields and various neighbouring crops) the problem of averaging and unfolding techniques (scaling-up) appeared important.

These are only some of the aspects connected with the proper use of the satellite signals, others being for example atmospheric corrections, day-night image superposition,etc.

From these considerations derived the need to organize a joint measuring campaign allowing to get the following points:

- Pooling the efforts of various European Institutes to perform the ground-truth measurements (great variety of parameters to be measured on a large test area)
- Creation of a data base of simultaneous or quasi-simultaneous ground, aircraft and satellite data
- Application and testing of evapotranspiration and soil moisture models (on bare soils and on soils with different crops)
- Atmospheric corrections calculation
- Scaling-up problems

The idea of this European Measuring Campaign was launched by the JRC during the Working-Group 2 meeting at Wageningen on November 1978. It was then decided to search for a proper area and the co-investigators were invited to send formal proposal for it. A French (Crau-Provence) and a German (Pattensen-Hannover) test areas were proposed.

A technical visit was made to the Crau site and a discussion followed in Avignon. The decision was made in favour of the German test site, mainly because of his large area (5 km x 4 km) of very homogeneous agricultural soil, fulfilling the conditions for the experiment.

In a meeting held at the end of March 1979 in Hannover all the scientific and organizational aspects of the experiment were analyzed and a detailed list of the tasks was established. On the basis of agrobioclimatological contraints, it was decided to realize the experiment in June 1979.
In fact the Joint European Measuring Campaign (JEMC) was performed from 4 to 24 June 1979.

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Fig. 1.1 Spatial distribution of TELLUS Test-sites within the European coverage area of the HCMM receiving stations of Madrid and Lannion

Tab. 1.1 TELLUS Test-sites, arranged in groups.

2. The Joint Measuring Campaign 1979 in Ruthe

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Introduction and objectives

The Joint Measuring Campaign 1979 in Ruthe was organized to study the water budget of an agricultural area, and to explore the possibilities of remote sensing as an aid in regional water budget studies. The Campaign was part of the work that is carried out in the Tellus Project on soil moisture and heat budget evaluations in selected European zones of agricultural and environmental interest. Elsewhere in this Volume (Chapter 1), S. Galli de Paratesi, the Principal Investigator of the Tellus Project, and Messrs. G. Tassone and F. Toselli of the JRC Staff report more detailed about the objectives of the Tellus Project and of the JEMC 1979.

In particular it comes out that use of HCMM data for soil moisture and soil heat evaluation in agriculture of Western Europe is complicated by the fact that the HCMM resolution is about 600 x 600 m (1 pixel = 36 ha).
Uniform areas of a size of 4-5 pixels, needed for a unique identification and interpretation of a single satellite signal (temperature or reflectivity) are not easily found. This means that the majority of HCMM signals, collected over Western Europe, are composite signals of non uniform plots that are much smaller than one pixel. Meaningful use of HCMM images thus requires the interpretation of composite signals.

Considering these aspects, the objectives of the Joint Measuring Campaign in Ruthe were the following ones:

1. Study in an agricultural area of about 4 x 4 km., with uniform soil and weather conditions, the water and energy budget of the local crop types at a number of locations by conventional means.

2. Collection on the ground at these locations (test plots), of:

   - temperature and reflectance data.

   - additional plant, soil and agrometeorological data needed to stimulate the exchange of heat, water and momentum between the canopy and the atmosphere, as well as crop and soil temperatures.

   - additional airborne signals on temperature and reflectance from an aircraft. Aircraft and satellite images can be used in scaling-up studies needed to evaluate the usefulness of HCMM data.

3. Collection of atmospheric parameter above tha test site (0-30 km) needed for atmospheric corrections of aircraft and satellite images.

4. Study of the thermal behaviour of a lake of the size of a large number of pixels in the vicinity of the test site.

It was believed that the area south of Hannover, in the vicinity of the village of Ruthe, fulfilled the prerequisites as far as soils, crops and field sizes were concerned, and that near Ruthe meaningful research could be carried out with respect to remote sensing and moisture and heat budget evaluations.

The Ruthe Area

An area of about 4 x 4 km, 15 km south of Hannover (West Germany) was chosen as test site for the Joint Measuring Campaign 1979. Fig. 1 gives an impression about the location of the test site in West Germany (about 52°N and 10°O). Also shown in Fig. 1 are the cities of Hannover, Braunschweig and Göttingen, where the German Institutes cooperating in the Campaign, are located. Also the location of the Steinhuder Meer, a lake with a size of about 30 km^2, is indicated. The Steinhuder Meer was also studied during the Campaign; elsewhere Bangert and Wilmers (Chapter 17) report on the measurements at the lake.

The area near Ruthe, along the Leine River, offers many favorable features with respect to water and energy budget evaluations, either by conventional methods or by remote sensing. The Ruthe area shows very little relief in an open landscape without trees, bushes or buildings. The soils, developed in a pleistocene loess layer of about 2 m thickness, are very homogeneous througrout large areas. The individual fields are large, with an average size of about 7.5 ha. Only three different corps cover during the growing season more than 95 percent of the entire area (wheat, barley and sugar beets). Detailed topographic, soil and other maps at various scales of the area are available. Some research facilities of the two universities of Hannover were already located on the chosen test site near Ruthe (among others an Experiment and Teaching Farm with lodging facilities and a 45-m high meteorological observation station). An advantage of being close to Hannover was the fact that the German Weather Bureau, located at the Hannover international airport, was interested in the Tellus Project. It provided detailed weather forecasts and performed four times a day radiosonde measurements between 0 and 30 km over the Hannover area. These measurements, in 50 m intervals, of temperature, humidity and wind velocity are needed for atmospheric corrections of remotely sensed crop and soil data.

The common crop rotation in the Ruthe area is sugar beets - wheat - barley - sugar beets. This means that about 2/3 of the area during the growing season is covered with cereals and 1/3 with beets. Usually cereals are sown during fall and sugar beets during April. As a consequence it can be expected that in May and June the water or energy budget of a wheat or barley field differs considerably from that of a young sugar beet crop. Since it was desirable to have some contrasts on the test site between fields with respect to water budget, energy budget, crop temperature and crop reflectance, it was decided to carry out the Joint Measuring Campaign during the early part of June. However, the general weather conditions for remote sensing purposes during June in the Hannover area are not favorable. A survey of weather data over the period 1951-1970 showed that

during June the percentage of the sky covered with clouds is 63. The number of days with a cloud cover greater than 80 percent is 9.4, whereas there are only 2.6 days in June with a cloud cover less than 20 percent (clear days). Nevertheless it was decided to start the Campaign on June 10, hoping that soon thereafter some bright days would occur. Hence conventional soil water and agrometeorological studies were conducted at 7 locations during the period June 10 - June 22. (2 wheat fields, 2 barley fields, 2 sugar beet crops and a 2.25 ha large bare field). Remote sensing by aircraft was performed on June 21 (day) and the following night (June 22). At the same time (June 21) the HCMM satellite passed over the Ruthe area to complete the program.

Topography and maps of the Ruthe area

Details about the test site can be seen on Fig. 2. This figure shows part of a topographic map 1:50000 of the Hannover area (Topographische Karte 1:50000, L 3724 Hannover). The boundaries of the test site are indicated as solid lines. For the present study only the area west of the Leine River was of interest. The individual plots, where soil water and agrometeorological measurements were taken, are all located west of the Leine River. They are shown in Fig. 5.
From Fig. 2 it can be seen that in general the area is slightly sloping towards the north. The highest elevation is between the villages of Schliekum and Oerie (about 80 m above sea level). East of Pattensen the altitude is about 70 m above sea level. Hence over a distance of 4 km there is only about 10 m difference in height. Also shown in Fig. 2 is the location of the Experiment and Teaching Farm ("Domäne Ruthe"), of one of the universities of Hannover, which served a home base during the Campaign. Also indicated, just north of the Domäne Ruthe, are orchards where horticulture experiments are carried out (with an irrigation pond, about which Wilmers and Gröning report elsewhere in this Report, chapter 16). Figure 2 is a section out of one of the various topographic maps that contain the Ruthe area. A number

of topographic maps exists, issued by the State of Niedersachsen (Lower Saxony), which contain the Measuring Campaign test site. At a scale of 1:100000 the Hannover area (and also the test site) is located on map nr. C3922. This map is subdivided in 4 maps on a 1:50000 scale. On this scale the map L3724 applies. This 1:50000 map in turn comprises four maps with scale 1:25000, one of which (nr.3724) contains the Ruthe area. This map (nr.3724) is subdivided in 25 maps with a scale of 1:5000. The test site near Ruthe is located on 4 such maps: Pattensen-Südost (3724, Nr.14), Ruthe-West (3724, nr.15), Oerie-Ost (3724, nr.19) and Schliekum-West (3724, nr.20). Besides the topographic maps 1:5000 (3724: 14, 15, 19 and 20) also soil maps and aerial maps denoted with the same code, are available. All maps can be obtained from either the "Niedersächsischen Landesverwaltungsamt - Landesvermessung", Warmbüchenkamp 2, 3000 Hannover or from the Katasteramt Hildesheim, Godehardsplatz 6, 3200 Hildesheim (West Germany).

The soils

Information about the soils of the test area can be obtained from either the soil map Hannover 1:100000 (Bodenübersichtskarte, 1969) or from the soil maps 1:5000 (Deutsche Grundkarte 1:5000, Bodenkarte auf der Grundlage der Bodenschätzung 1964) 3724/14,15,19 and 20. The maps also contain information about the geological formations which act as parent material for the various soil types.

Figure 3 is part of the Bodenübersichtskarte (1969) and shows the test area with the two soil types that occur. The northern part of the test site exists of "Parabraunerde" (gray brown podzolic soil) denoted with the symbol 8L, the southern part (9L) also shows "Parabraunerde", with the addition "oft pseudo-vergleyt = usually hydromorph". Both soil types are derived from the same parent material (a pleistocene loess). The main difference between the two soil units stems from the depth of the water table. In the southern part the ground water table is within 2 m from the soil surface, in the north the water table is deeper

than 2 m. In the northern part no artificial drainage system is requiered. In the southern part many fields are drained by tiles and a ditch system is maintained to discharge the drainage water. Figure 3 is derived from the soil map Hannover 1:100000 (Boden-Übersichtskarte, 1969). The soil maps 1:5000, 3724/14,15,19 and 20 show a more differentiated picture of both soil type.
During the Campaign soil pits were dug at 6 of the 7 test plots, that were investigated. They were about 2 m deep. This pits were used for a description of the local soil profile. Also the root distribution of the various crops was determined in these pits. Furthermore soil samples were taken in various depths for the determination of the hydraulic properties of the soil horizons. Figure 4 shows schematically 5 soil profiles. Soil types and soil horizons are classified according to the Arbeitsgemeinschaft Bodenkunde (1971). The general texture of all profiles is silt to silt loam in the upper 50 cm, from 50 to about 140 cm it is silt loam and below 140 cm it is sand. The location of the profiles is shown in Fig. 5. As indication for the spatial homo-

genity of the loess deposits Table 1 is shown. It shows the partition of the clay, silt and sand fraction in the top soil of 5 different fields that were studied during the Campaign. It is assumed that other physical properties of the soils show just as little variation. The high degree of spatial homogenity was one of the reasons why the Ruthe area was chosen as test site.

<u>Crops and field sizes</u>

Three crops occur predominantly on the test site: wheat (Triticum aestivum L.), barley (Hordeum vulgare L.) and sugar beets (Beta vulgaris L.). The most common crop rotation is sugar beets - wheat - barley - sugar beets - etc. Occasionally one also finds rye, peas and small plots with vegetables. About 2/3 of the area

is occupied in the Ruthe area by cereals, the other 1/3 by sugar beets. The 4 x 4 km test site is cultivated by nearly 150 different farmers. The average field size is about 7.5 ha. However, much larger and much smaller individual plots do occur. The different crops, together with the nonuniform field sizes, cause a characteristic pattern of light and dark rectangles on aerial photographs and maps. To interprete such aerial maps, which were prepared at the end of April 1979 by the State of Niedersachsen (Deutsche Grundkarte 1:5000, Luftbildplan 3724/14, 15,19 and 20, 1979) it was decided to make a crop survey and prepare a crop map. This was done with use of the forementioned aerial photographs 3724/14, 15,19 and 20 by the Institut für Bodenkunde und Waldernährung of the University of Göttingen. Wheat, barley, sugar beets and some other crops were separated, but no distinction was made between winter and spring cereals. Neither the stage of development of each crop was determined during this survey. Copies of these crop maps (1:5000) may be requested from the authors or from the Joint Research Centre in Ispra.

Detailed investigations about the phenology of the crops were carried out at different locations on the test site. Von Hoyningen-Huene et al. in their contribution list a number of phenometrical data of a sugar beet and a barley crop, Beese and Schlichter determined the leaf area index, biomass and crop height, Milton collected crop reflectivity and emissivily data and Köpke and Böhm studied the root distribution of a number of crops.

The individual test plots

Within the entire test site of about 4 x 4 km, seven fields were chosen for detailed soil, plant and agrometeorological measurements during the Campaign. Additionally an irrigation pond at the Experiment Farm was studied and measurements in various heights on the 45-m high weather observation station were taken. Of the seven plots, one was located on a fallow field of 2.25 ha size, and two test plots were either in a wheat, a barley or a sugar beet field. The location of each plot, and also of the irrigation pond and the weather station, can be seen on Fig. 5. A description

of the measurements taken at each plot can be found elsewhere throughout this Volume. The test plots (Fields) were numbered one through seven. Throughout the entire report Field Nr. 1 will refer to the fallow plot, Nr. 2 to the sugar beet field near the Experiment Farm, Nr. 3 to the barley field at the Farm, Nr. 4 to the wheat field west of Schliekum, Nrs.5,6 and 7 to the sugar beet, barley and wheat fields along the road between Jeinsen and Pattensen. On Fields 1,2 and 3, on land belonging to the Farm, electricity from the Farm was available, on Fields 4,5,6 and 7 there was no power supply and measuring and recording equipment was battery-operated. Field Nr. 1 was investigated by a team from the Joint Research Centre in Ispra, Fields Nrs. 2 and 3 by the Zentrale Agrarmeteorologische Forschungsstelle des Deutschen Wetterdienstes in Braunschweig, Field Nr. 4 by the Institut für Bodenkunde und Waldernährung der Universität Göttingen, and Fields Nrs. 5,6 and 7 by a team from the United Kingdom. Soil water studies on all fields were conducted by the Institut für Bodenkunde und Waldernährung from Göttingen, in cooperation with the Bundesanstalt für Geowissenschaften und Rohstoffe and the Niedersächsisches Landesamt für Bodenforschung, both in Hannover. Root distribution studies finally, on Fields Nrs. 2,3, 4,5 and 6, were performed by the Institut für Pflanzenbau und Pflanzenzüchtung of the University of Göttingen.

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Deutsche Grundkarte 1:5000 Luftbildplan, Maps Pattensen-Südost, Ruthe-West, Oerie-Ost and Schliekum (corresponding to the topographic map 1:25000, nr. 3724 the numbers 14,15,19 and 20). Issued by the State of Niedersachsen (Niedersächsisches Landesverwaltungsamt-Landesvermessung), 1979 edition.

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LEGEND TO FIGURES AND TABLES OF CHAPTER 2

Fig. 1 Topographical map of West-Germany, with the location of the Joint Measuring Campain test site near Ruthe.

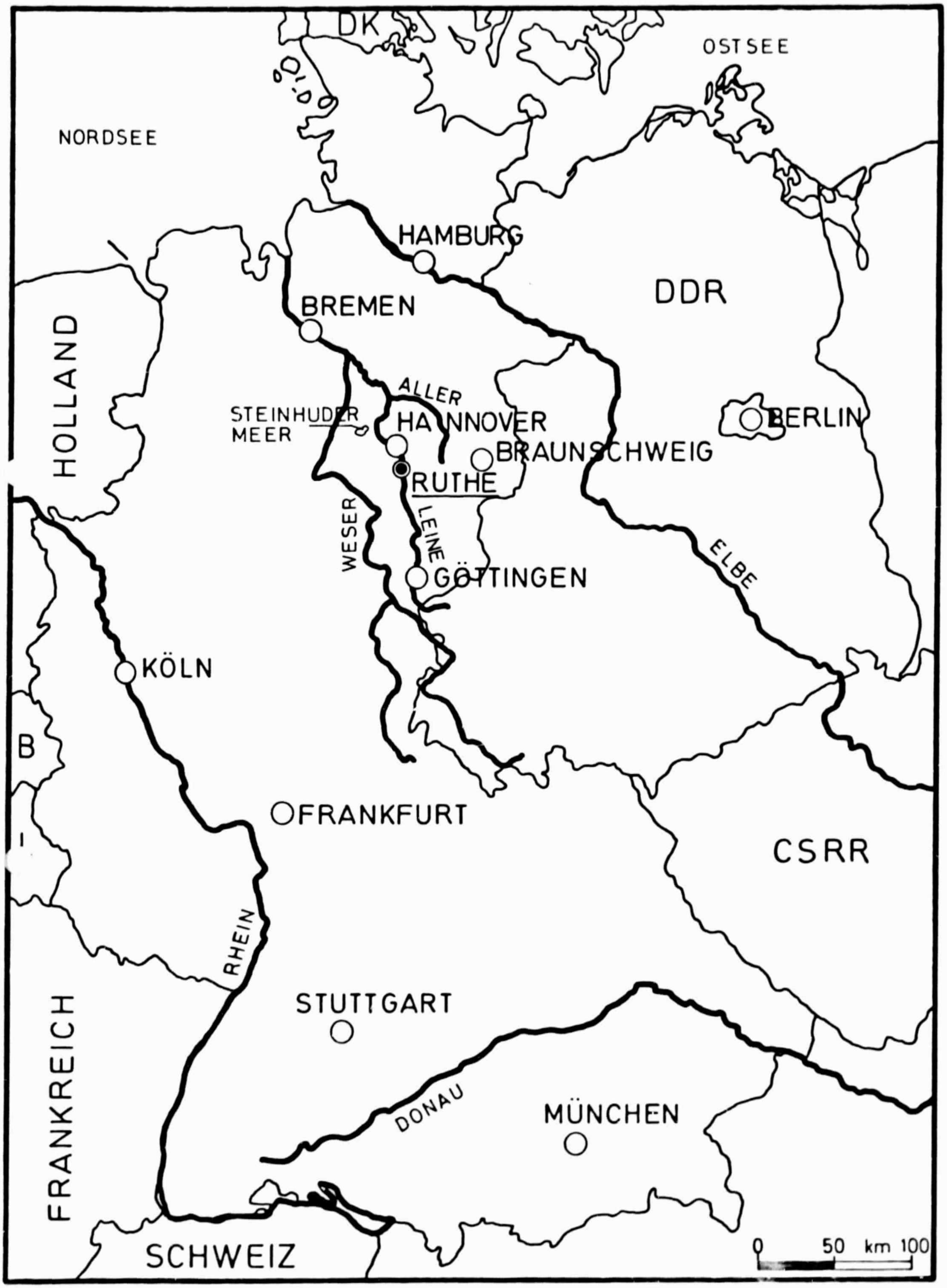
Fig. 2 Part of the topographical map 1:50000 (Topographische Karte 1:50000, 1975) showing details of the 1979 test site.

Fig. 3 Section from the soil map 1:100000 (Bodenübersichtskarte, 1969) with the soil types of the test site.

Fig. 4 Schematical representation of the soil profiles on the test site at Fields Nr.1,2,3,4 and 6.

Fig. 5 The test site on a scale 1:25000 (Topographische Karte 1:25000, 1979), showing the location of the Fields Nr.1,2,3,4,5,6 and 7, together with the irrigation pond and the meteorological observation tower near the "Domäne Ruthe".

Table 1 Particle size distribution in the top soil of Fields Nr. 1,2,3,4 and 6 at Ruthe.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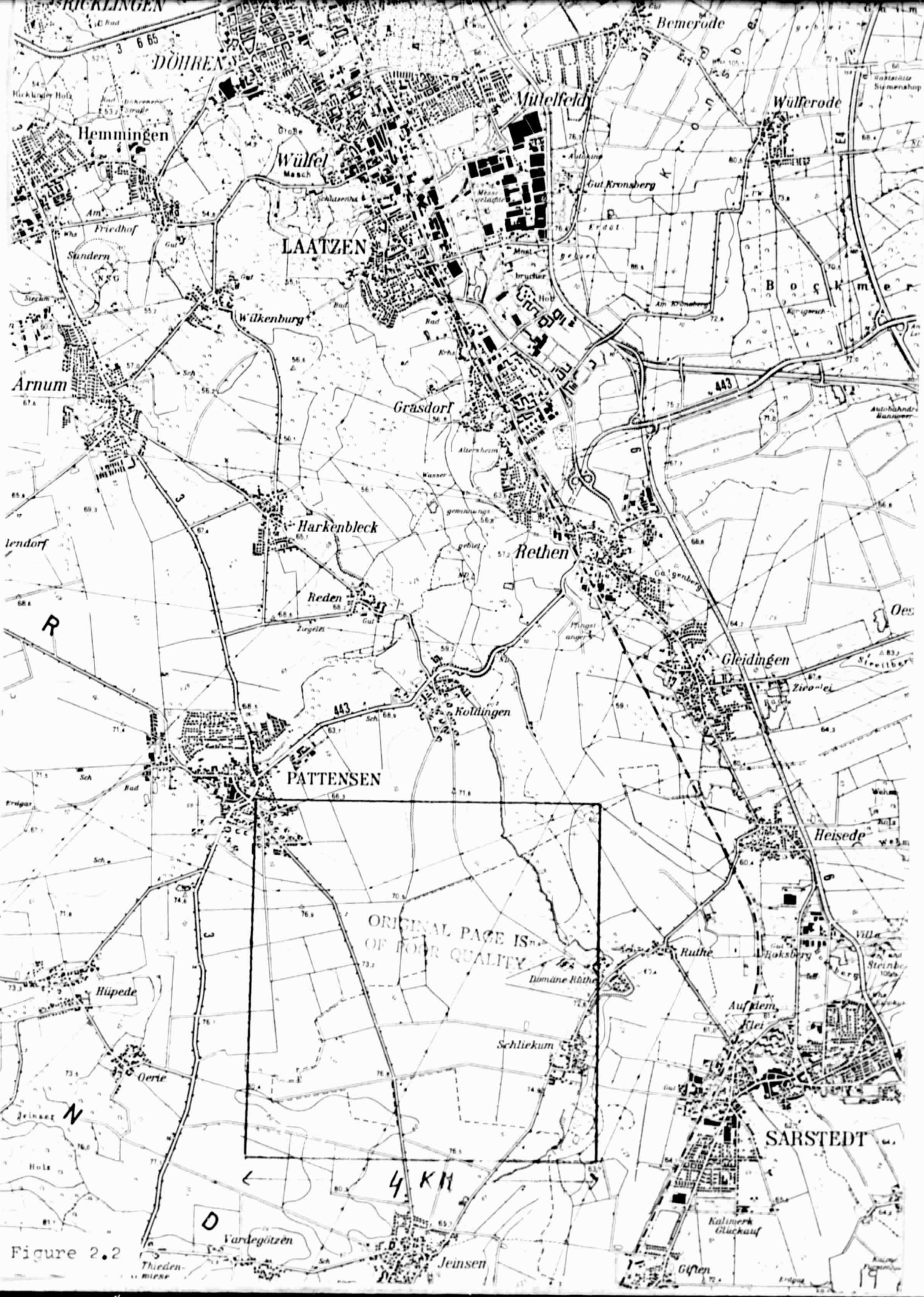
SCHWEIZ

Figure 2.1



RICKLINGEN
DÖHREN
Bemerode
Mittelfeld
Wülferode
Hemmingen
Wülfel
Gut Kronsberg
Friedhof
Sundern
LAATZEN
Wilkenburg
Arnum
443
Grasdorf
Altersheim
Harkenbleck
Rethen
Reden
Gleidingen
443
Koldingen
PATTENSEN
Heisede
Ruthe
Domäne Ruthe
Hüpede
Schliekum
Oerie
SARSTEDT
Kaliwerk Glückauf
Vardegötzen
Jeinsen
Thieden-wiese
Giften
4 KM

Figure 2.2

ALLUVIAL SOIL OF THE LEINE VALLEY

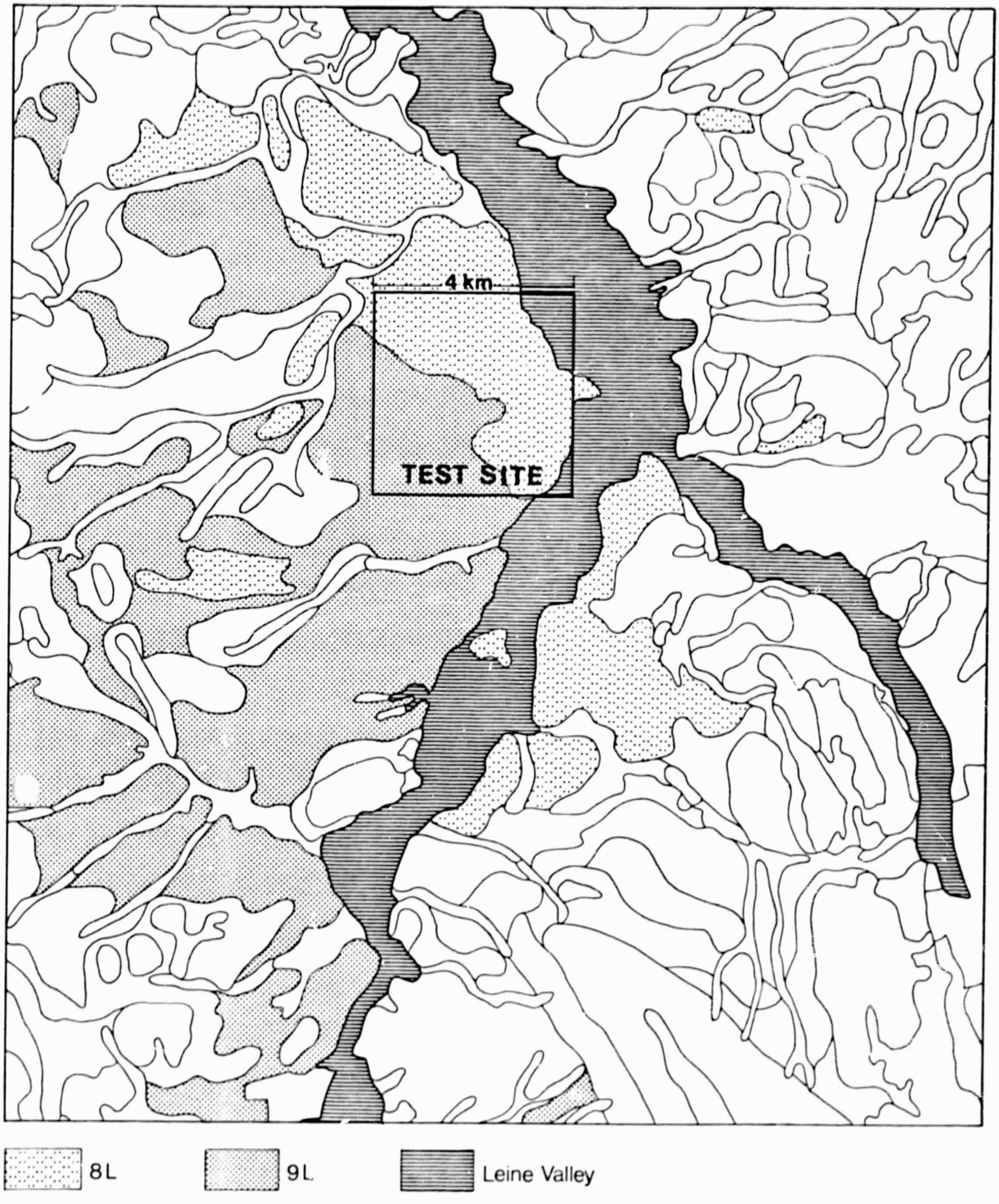
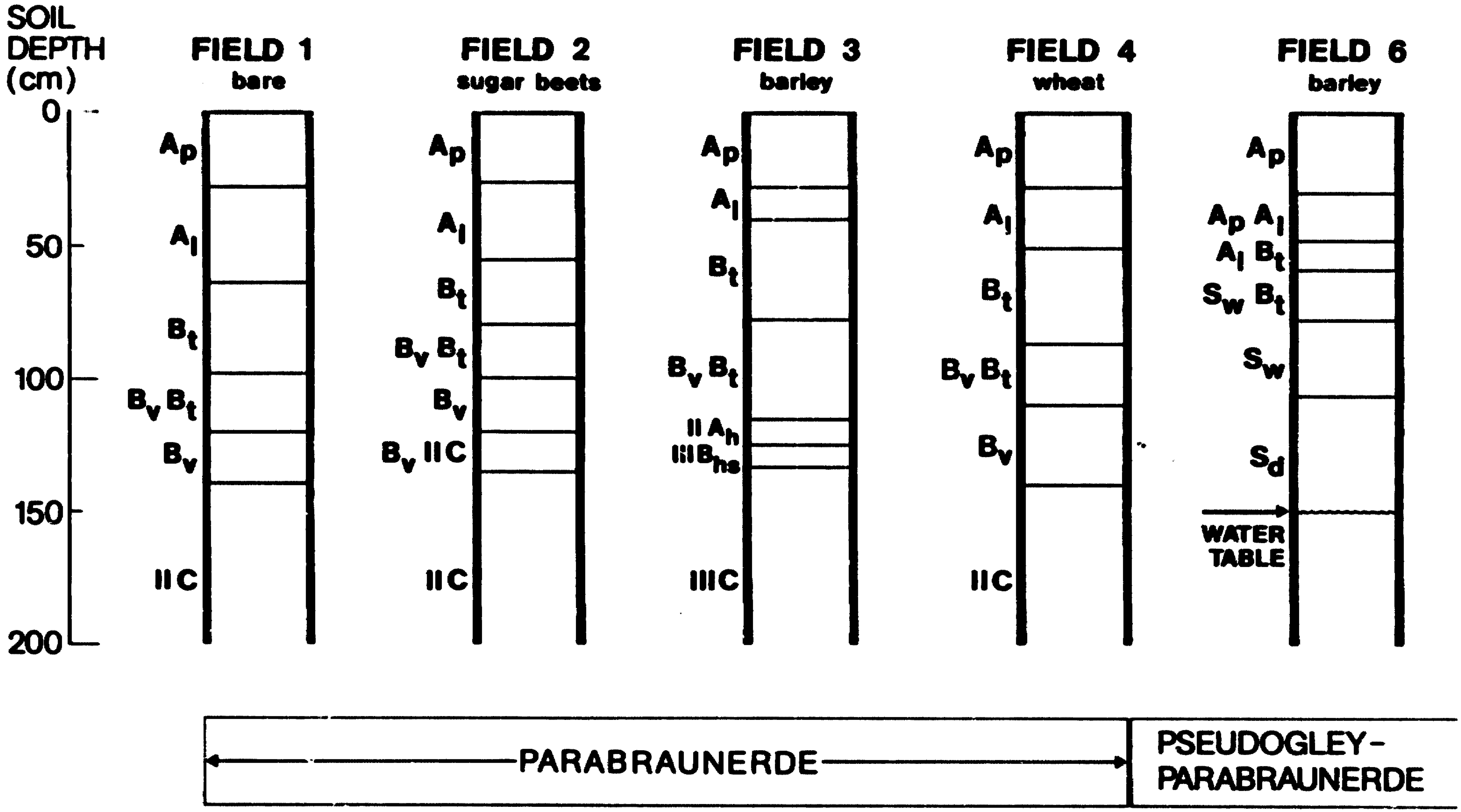


Fig.2.3

Fig.2.4



SOIL DEPTH (cm)
0
50
100
150
200
FIELD 1
bare
A_p
A_l
B_t
B_v B_t
B_v
II C
FIELD 2
sugar beets
A_p
A_l
B_t
B_v B_t
B_v
B_v II C
II C
FIELD 3
barley
A_p
A_l
B_t
B_v B_t
II A_h
IIIB_{hs}
III C
FIELD 4
wheat
A_p
A_l
B_t
B_v B_t
B_v
II C
FIELD 6
barley
A_p
A_p A_l
A_l B_t
S_w B_t
S_w
S_d
WATER TABLE
PARABRAUNERDE
PSEUDOGLEY-PARABRAUNERDE

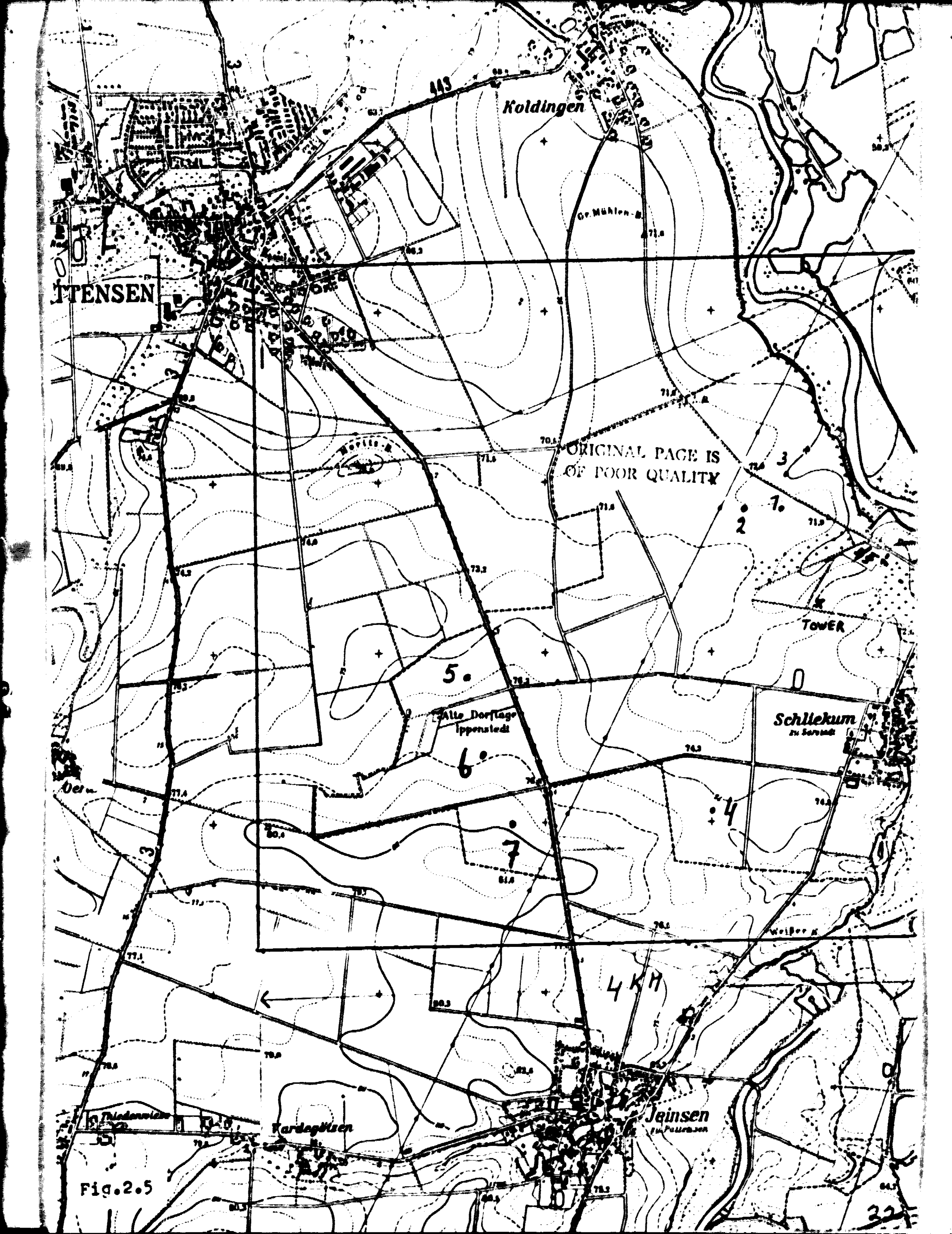

Koldingen
Gr. Mühlen-B.
TTENSEN
1.
2
3
4
5.
6.
7
TOWER
Schliekum
zu Sarstedt
Alte Dorflage
Ippenstedt
4KM
Jeinsen
zu Pattensen
Vardegötzen
Thiedenwiese

Fig.2.5

	FIELD NUMBER				
	1	2	3	4	6
CLAY $<2\mu$	10.0	9.2	9.6	11.2	10.8
LOESS 2-20μ	20.2	23.0	21.9	22.7	21.9
LOESS 20-60μ	61.3	59.0	59.0	59.5	61.9
SAND $>60\mu$	8.5	8.8	9.5	6.6	5.4

Table 2.7

3. Aircraft and Satellite Data

F. Toselli

Joint Research Centre of the European Communities,
Ispra

3.1 Introduction

As mentioned in the previous paragraphs the test area chosen for the EJMC is located near Pattensen (West Germany) at a latitude of 52° 15'N.

Although the soil and vegetation conditions were almost ideal for the measurements to be performed, the rather unfavorable weather conditions (statistically: 9,4 days with cloudiness higher than 80% and only 1,4 days lower than 20% in June) required that the firm doing the flight were able to meet a very probable long stand-by period.

Many European firms answered the call for tender, but finally the choice fell on one which offered an unlimited stand-by at a reasonable cost.

3.2 The aircraft flights

The firm: Spacetec Datengewinnung G.m.b.H.
Erbprinzenstrasse 11 - Freiburg (West Germany)
associated with
Hansa Luftbild
Münster (West Germany)

Equipment: The aircraft employed was a twin-engines Aircommander equipped with the following instruments:
DAEDALUS MSS, 7 visible (VIS) channels + 1 thermal infrared (TIR) channel (see Table 3.1)
Magnetic tape recorder SANGAMO
False colour camera Zeiss RMK - Objective PLEOGON A2 f=153,14 mm - 20% lateral overlapping
False colour quick-look restitution equipment
Radio link with the ground

Period: The period chosen was the best for vegetation and climatic conditions for that region.
The aircraft based at Münster-Osnabrück (for day-flights) and Hannover (for night-flights) airports was on stand-by starting from the 8 June 1979 on.

TABLE 3.1

Aircraft	DAEDALUS 1260			
FOV (total)	90°			
IFOV	2.5 mr			
	λ_c nm	$\Delta\lambda$ nm	$NE\Delta\rho$ %	$NE\Delta T$ °C
Channel 4	525	50	<0.3	
Channel 5	575	50	<0.2	
Channel	625	50	<0.2	
Channel 7	670	40	<0.2	
Channel 8	745	90	<0.3	
Channel 9	845	90	<0.5	
Channel 10	965	90	<1.0	
	µm			
Channel 11	8.5 + 14			<0.2

3.3 Specific flight characteristics

Altitude: 500 m (3 lines of flight covering all the test areas)

1000 m
3000 m (or more) } full test site coverage with 30% overlapping

Flight times: day flight between 13.00 and 15.00 local time
night flight between 2.30 and 3.30 local time
Day and night flights to be performed in sequence.

3.4 The Flights

As already said in the preceding paragraph the weather forecast was done twice a day (9.30 and 17.00) by the Institute of Meteorology and Climatology of the Hannover University and the flying crew, in stand-by, was immediately informed by the responsible of the campaign (see Chapter 2).

This period was characterized by continuous atlantic perturbations and only around the 17 June began a pressure rise. The first day flight was performed from 14.14 to 15.17 of 20 June with good weather conditions.
Unfortunately the quick look (at 19.00 at the Münster Airport) showed a not satisfactory performance of the scanner (some noise in the thermal channel). Moreover, the flying crew refused to do the sequential night flight presuming that the weather conditions were going to worsen.
So the day flight had to be repeated and the whole operation took place on the 21 June from 12.30 to 14.08 and on the 22 June from 1.58 to 3.14.
The lines of flight are shown in fig. 3-1. During the night the lines of flight N.7,8 and 9 at 500 m height were given by flash lights positioned on the field.
Immediately after the night flight the weather condition worsened definitively and around 6.00 of the 22 June it started raining.

3.5 Satellite

On the base of meteorological weather forecast it was tried to combine the aircraft flights with the satellite overpasses (underflight experiment). To do this it was agreed with NASA that in the period 15 ÷ 30 June 1979 the satellite radiometer should have to be switched on at every passage on the test area.
Table 3.2 gives the satellite passages over the test area in that period.

3.6 Data restitution to JRC and distribution to participants

Aircraft:	MSS quick looks	flight	21-6 day
			22-6 night
	false colour transparencies	flight	20-6 day
			21-6 day
	CCTs	flight	21-6 day
			22-6 night

HCMM:

The following images and CCTs (radiometrically but not geometrically corrected) of the Pattensen area (row N.5) are available:

Date '79	N/D	Orbit	Nr JRC
01 June	N	5935	2434
11 June	D	6090	2435
27 June	N	6320	2436
12 July	D	6549	2437
13 July	D	6564	2438

This imagery is the only one having a fairly low cloud cover around the period of the campaign.

TABLE 3.2

Day	d/n	Time GMT	track
15 June	d	11.17	14
16	n	0.50	15
16	d	11.35	15
17	n	0.05	16
17	d	11.53	16
18	n	0.50	1
21	d	11.40	4
22	n	0.25	5
22	d	12.00	5
23	n	0.43	6
26	d	11.50	9
27	n	0.50	10
27	d	11.45	10
28	n	0.45	11

3.7 Radar

It was considered useful to collect also radar data on the same test area, possibly at the same time of aircraft and satellite passages to test the possibility of application of radar techniques as far as soil moisture detection is concerned.
Due to the previous engagements the firm chosen declared to be available for flying on July 18th only, but owing to the poor weather conditions the operation failed.

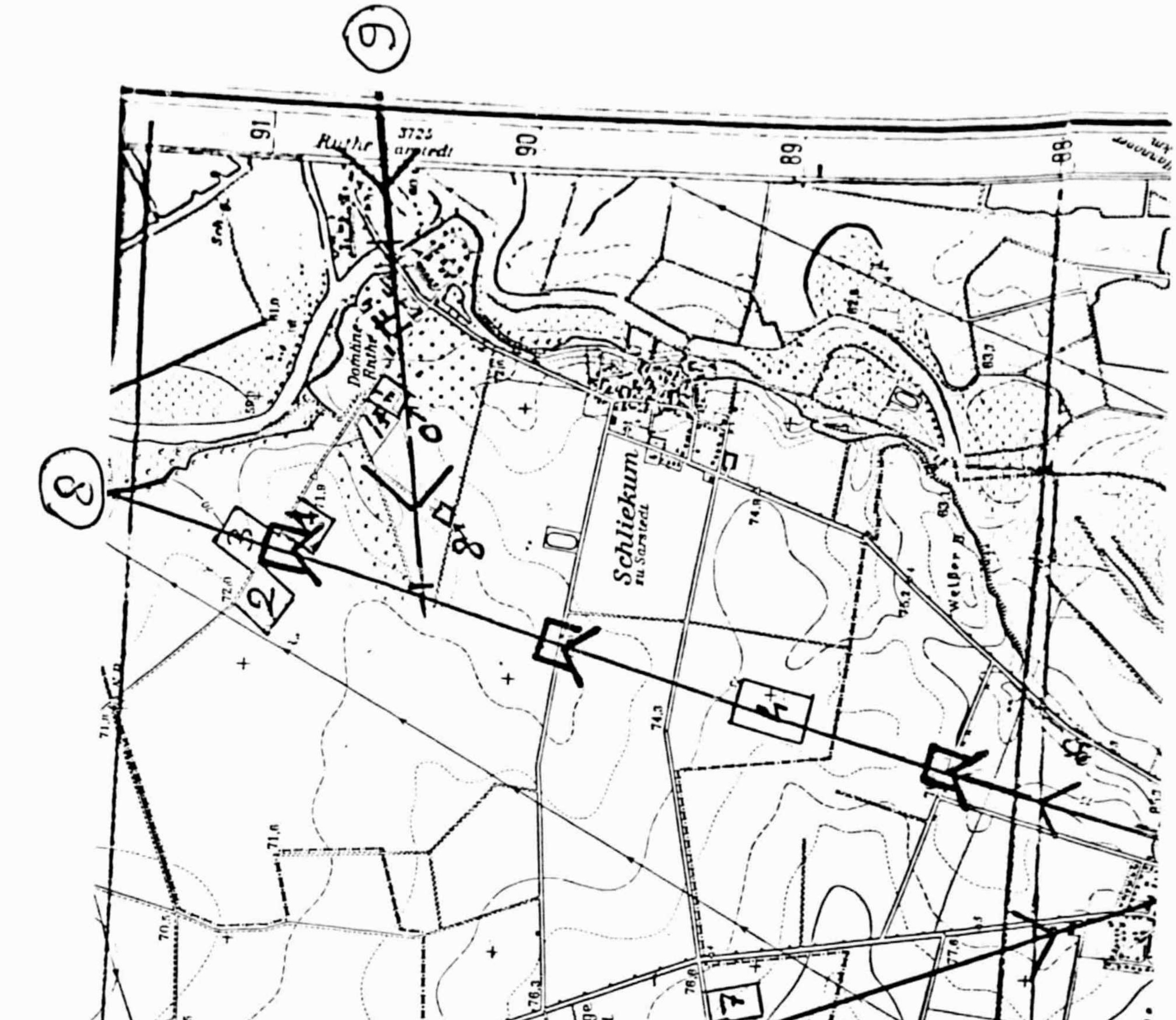


Fig. 3.1 Flight lines at 500 m.

4. Weather Conditions during the Campaign

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Institut für Meteorologie and Klimatologie der
Technischen Universität, Hannover
Herrenhäuser Straße 2, 3000 Hannover 21

Summary

The Institute of Meteorology and Climatology of the Technical University of Hannover, participated in the Joint Measuring Campaign 1979 near Ruthe in a number of ways. In this report of brief description about the Institute's routine measuring program, maintained in Ruthe and in Hannover-Herrenhausen is given. In both places the Institute performes daily observations with the use of two well-equiped weather stations. The data collected at both places during the Campaign can be used to characterize the local weather during the time of the Campaign. Furthermore the Institute, in cooperation with the German Weather Bureau, which operates a weather station in Hannover-Langenhagen at the airport, furnished daily weather forecasts to help select in advance best conditions for the flight experiment. Also about these activities will be reported here.

Climatic Conditions of the Hannover Area

The Hannover area is situated in the transition zone between the North German Plain (Norddeutsche Flachland) and the Northwestern German Piedmont area (Nordwestdeutsche Berglandschwelle). For many years the Institute of Meteorology and Climatology of the Technical University of Hannover has carried out measurements to characterize the regional climate and to describe the weather of the area. Also the German Weather Bureau in Hannover-Langenhagen maintains an intensive measuring program. The location of the weather station of the Weather Bureau in Hannover-Langenhagen, as well as the observation stations of the Institute of Meteorology and Climatology, in Hannover-Herrenhausen and in Ruthe, are shown in the first figure. On request the following

information, either from the German Weather Bureau or from the Institute of Meteorology and Climatology, can be obtained: Europäischer Wetterbericht (daily issues), Die Großwetterlagen Mitteleuropas (monthly issues), and Synoptische Wetterkarten, all prepared by the German Weather Bureau in Offenbach, further the Tägliche Beobachtungen (daily observations), issued by the Weather Bureau in Hannover, and Tägliche Beobachtungen in Hannover-Herrenhausen and Ruthe (prepared by the Institute of Meteorology and Climatology of the Technical University of Hannover). All sources mentioned were used during the Campaign and for the preparation of this report.

Langenhagen, the station of the Weather Bureau of Hannover, is located, together with the climatic main station, the synoptic and radiosonde station, north of the city in an open area. In the vicinity the terrain is partly covered by pine forest or farmed. There are also some built-up regions with a sandy soil and partly cultivated swanps. Herrenhausen is a station of the Institute of Meteorology and Climatology situated in the outskirts of the city of Hannover in a partly open area with houses and other buildings. At the station wind and temperature profiles up to 50 m height are measured besides the routine climatic observations. In addition the actual evaporation is determined by floating lysimeters. The station of Ruthe is situated south of the city in a loess region.

Transitions between oceanic and continental conditions can be observed in the regional climate, as shown by investigations of Hoffmeister (1930,1942). Löpmeier (1979) also pointed out the oceanic and continental elements in temperature and precipitation regime of Hannover. From their investigations, as well as from the work of Wilmers (1968, 1975) and by Pohler (1976) it has become clear that the temperature regime in Herrenhausen is clearly influenced by the city of Hannover in contrast to Langenhagen and Ruthe. The three weather stations do not only reveal transitional conditions as far as precipitation and temperature are concerned. Driftmeyer (1976) states also considerable differences in the wind regime between the three stations, which indicates the influence of the mountanous highland in the

south on the general wind pattern. This might explain the lower amounts of precipitation south of Hannover, which in turn influences the water budget of the loess area near Ruthe.

With respect to the foregoing remarks it can be concluded that the Hannover area is located in the west-wind belt of the planetary circulation system. Therefore the weather during summertime is ruled by the European "Summer Monsoon". During the "Summer Monsoon" relatively cool and moist air masses are conveyed by westerly winds from the Ocean into Central Europe. Changing weather conditions with high precipitation rates are dominating. Such conditions usually occur in the middle of June, at the end of July and in the beginning of August. High pressure situations with warm and dry days are to be found more frequently in the late summer starting in the middle of August. The wind direction then turns from WNW to S and SE.

The maximum precipitation occurrences are reached in July under influence of the "Summer Monsoon". Then the average cloudiness is higher than in the other months of the summer. In August and September longer periods with little precipitation and longer sunshine duration occur.

The Weather During the Joint Measuring Campaign 1979

Compared to the long-term climatic average values the month of June 1979 was too warm and too dry for the Hannover area. Cyclonic general weather situations occurd only on 3 days (normally 13 days). The month was dominated by anticyclonic situations on 27 days (normally 17 days).

Among the types of circulation the zonal one was completely missing (normally occurring on 8 days). The meridional type of circulation exceeded with 13 days the average occurance by one day. With 17 days instead of 10 the mixee type of circulation prevailed.

Methods of observation

During the period from June 11 to June 22, local forecasts were made for the Hannover area twice a day by the Institute for Meteorology and Climatology. The basic data for the forecasts consisted of the actual weather charts and prognostic charts of the German Weather Service and own observations of clouds and weather by the institute-owned climatic stations at Hannover-Herrenhausen and Ruthe. Radar-observations of clouds and precipitation zones performed at the Weather Bureau of Hannover-Langenhagen and Hamburg-Fuhlsbüttel were further aids for the construction of the forecasts.

For the evaluation of the weather situation the determination of the cloud type and the total cloud cover were especially considered. The temperature initiating convective cloud formation was taken from radiosonde measurements. Changes of the general circulation as well as changes of airmasses and frontal passages could be early recognized from synoptic weather charts. With knowledge of the local climate, it was possible to give a definite forecast for at least 12 hours and a further outlook for 24 hours with the aid of synoptic weather charts and local weather observations.

The weather between June 11 and June 22, 1979

A ten days-period of sunny and warm weather ended on June 11. After that a low over Western Europe started to dominate the weather in North Germany. At its front part intermittent advection of cool and warm oceanic air-masses took place by southwesterly winds for the whole of Germany. On all days from the 11th to the 16th it remained mainly cloudy (6/8) in North Germany. On all days there was rainfall of medium intensity. For the 6 days a total amount of precipitation of 14.4 mm was registered in Ruthe. During this period the temperature decreased remarkebly and between June 15 and 17 a negative deviation of 5^{O}K from the average climatic values was noticed. On the 16th the center of the depression was situated over North Germany. At the same

time the anticyclone over the eastern Atlantic ocean intensified. Therefore cool and cloudy polar air streamed into the northern part of Germany.

A considerable increase in the air pressure over the British Isles and the Benelux-Countries led to an eastward expansion of the Atlantic anticyclone until the evening of the 17th. From the 17th to the 20th of June it remained dry under high pressure conditions in North Germany. At the eastern flank of the blocking anticyclone very moist air was conveyed from the north into the northern parts of Germany. This air mass was still cold in the lower tropospheric layers while it was already strongly warmed in the upper layers. In the 850 mbar-level above Hannover the temperature amounted to 10^{o}C on the 18th of June at noon (GMT).

The inversion just below this level was preserved so that low Stratus-clouds coming from the north could not be dissolved. On the 19th the situation and the intensity of the anticyclone with its centre over the British Isles did not change. Dryer air now streamed into the northeastern parts of Germany but in the Hannover-area the stratiform cloud cover was preserved (8/8 St).

Around noon the cloud cover broke up reaching a total amount of cloud of 4/8 Sc. The daily duration of sunshine of less than 5 hours, compared to an astronomical possible duration of about 17 hours, elucidates the weather character. The misty and cloudy period ended on June 20. The dominating anticyclone moved, slightly weakening, eastwards across North Germany and so in the lower troposphere the wind turned to easterly directions. The 24 hour prognostic chart of the German Weather Service for the 21st of June, 6 GMT showed the center of the anticyclone over the Baltic area.

The night from the 20th (18 GMT) to the 21st (6 GMT) remained cloudless. During the night the best meteorological conditions for the flight experiment were encountered. A low water vapor content of the air and the cloudless sky for over 12 hours favored the long-wave emission of the ground and caused the significant temperature differences between the individual canopies.

Horizontal visual ranges from 3 to 6 km for the period 0 GMT to

2 GMT were reported by the Weather Bureau in Hannover-Langehangen. Even though the visibility changed with height the visual range was more than 10 km in the heighs of 600, 1000 and 3000 m. The slant visibilities must have been not so favorable. The decrease in visibility was caused by the nocturnal inversion reaching from the ground up to 250 m height. Here the slant visual ranges were around 3 km. Such inversions contribute to a decrease in visibility by enrichment of the air with haze particles, especially during the daytime at night. Unfortunately it was impossible, because of technical difficulties, to arrange a remote sensing flight during this night. It had to be postponed till the next day (June 21 daytime and June 22 at night).

The prediction of cloud conditions for June 21 proved to be difficult since in the course of the day the formation of convective clouds was expected. The formation of Cumulus-clouds started at 9 o'clock GMT, their vertical extent remaining small. During the flight measurements at about 12 GMT the maximum cloud cover was reached in Ruthe with 4/8 Cu. The convective clouds were dissolved right after sunset. Already at 18 GMT only 1/8 Ac were observed. Until midnight the cloud situation did not change. At 0 GMT of the June 22 it was cloudless. After ending the flight measurements high Ci-clouds started to spread over the sky at 2 GMT. Already at 4 GMT the sky was overcast by clouds. The vertical extent of the clouds increased and thunderstorms developed in the early morning due to a cold front passing from the west which initiated another period of cloudy weather.

Illustrations of the weather charts from 6 GMT demonstrate the weather situation on the 21st and 22nd of June. The general weather situation can be taken from climatic diagrams of Ruthe. The daily means of temperature as well as its extreme values, precipitation, duration of sunshine, wind speed and wind direction for the period from the June 11-25 are tabulated in Fig. 2. Fig.3

shows the course of the weather from June 21, 6 GMT until June 22, 6 GMT in Ruthe. Finally, as Figs. 4, 5 and 6 weather charts for June 21, 22 and 23 are presented for illustration purposes.

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LEGEND TO FIGURES AND TABLES OF CHAPTER 4

Fig. 1 Map of Hannover area

Fig. 2 Sequence of weather data from June 11th to June 25th,1979
- a) precipitation in mm, Ruthe
- b) air temperature in $^{\circ}C$, Ruthe
  - extreme values
  - actual daily mean temperature
  - long-term yearly mean air temperature
- c) daily vapor pressure in mbar, Ruthe
- d) duration of sunshine in h, Langenhagen
- e) air pressure in mbar, Ruthe
- f) wind speed in $m\ s^{-1}$, Ruthe
- g) wind direction in degrees, Ruthe
- h) cloudiness in octas, Ruthe

Fig. 3 Weather data from 21-6-1979, 00 CET to 22-6-1979, 24 CET
- a) hourly values of air temperature in $^{\circ}C$, Ruthe
- b) actual vapor pressure in mbar, Ruthe
- c) global radiation in $MJ\ m^{-2}$ Herrenhausen
- d) cloudiness in octas, Ruthe

Fig. 4 Weather chart of 21-6-1979, 6 GMT

Fig. 5 Weather chart of 22-6-1979, 6 GMT

Fig. 6 Weather chart of 23-6-1979, 6 GMT

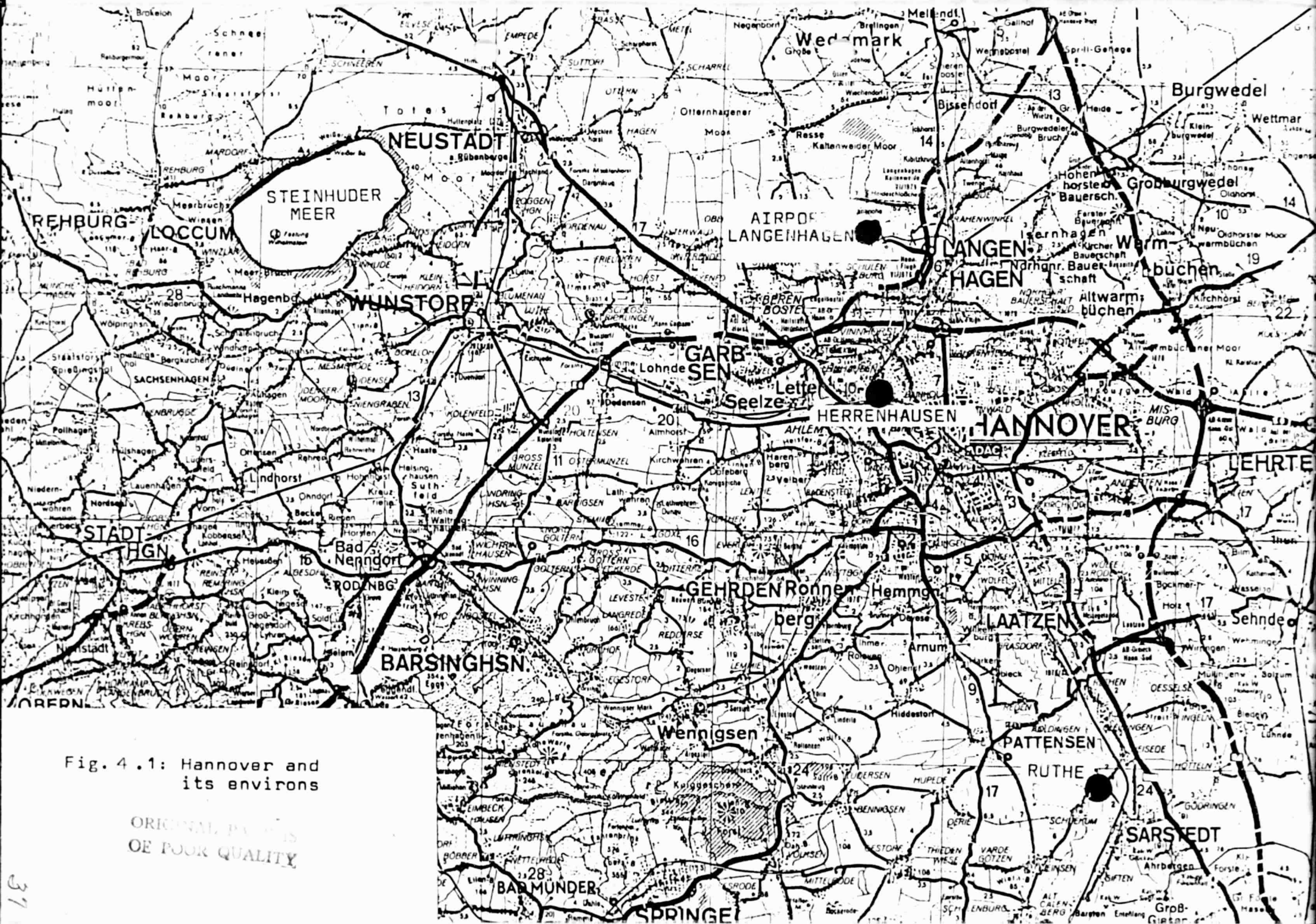


Fig. 4.1: Hannover and its environs

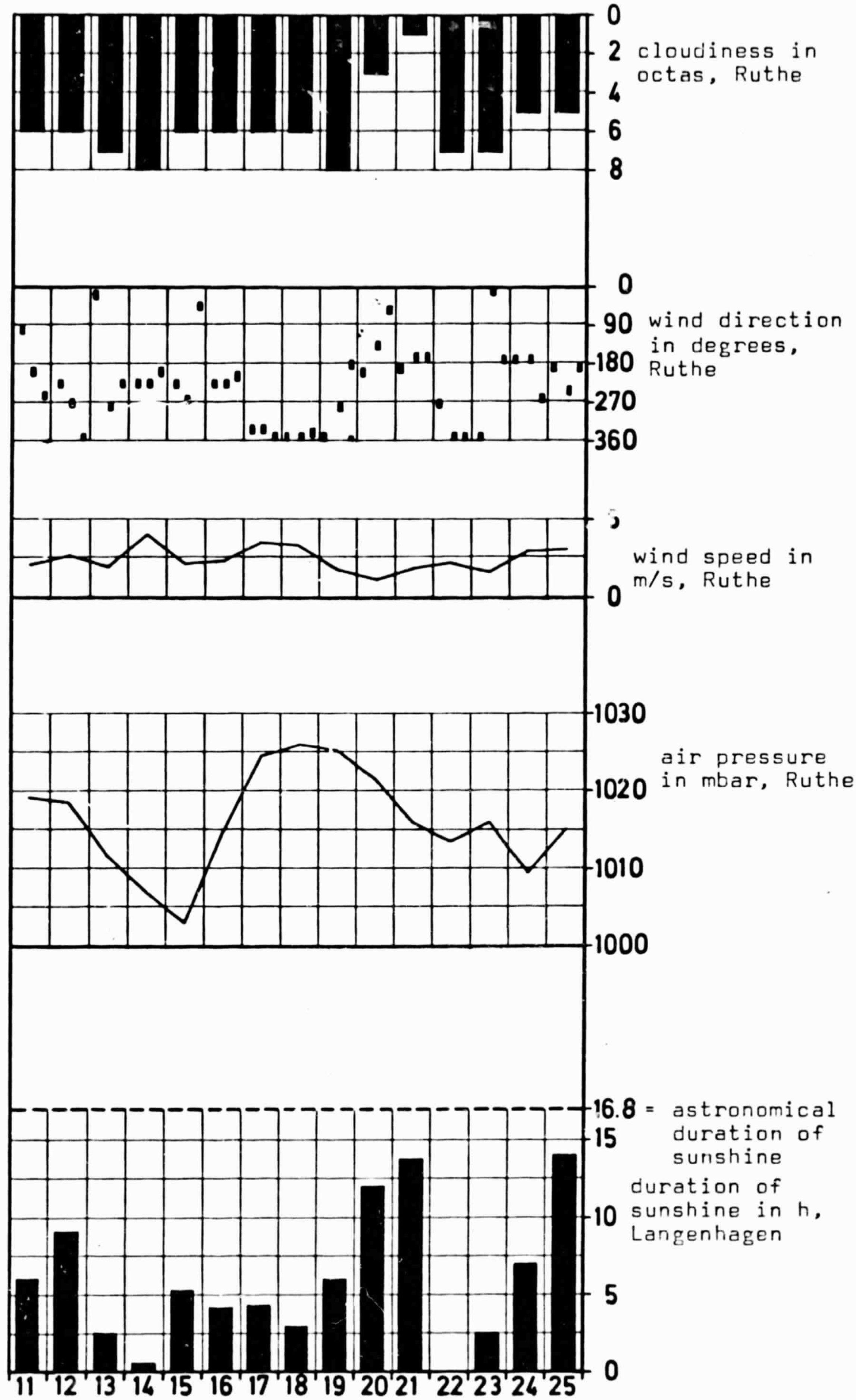


Fig. 4.2.1 Sequence of weather from June, 11th to June 25th

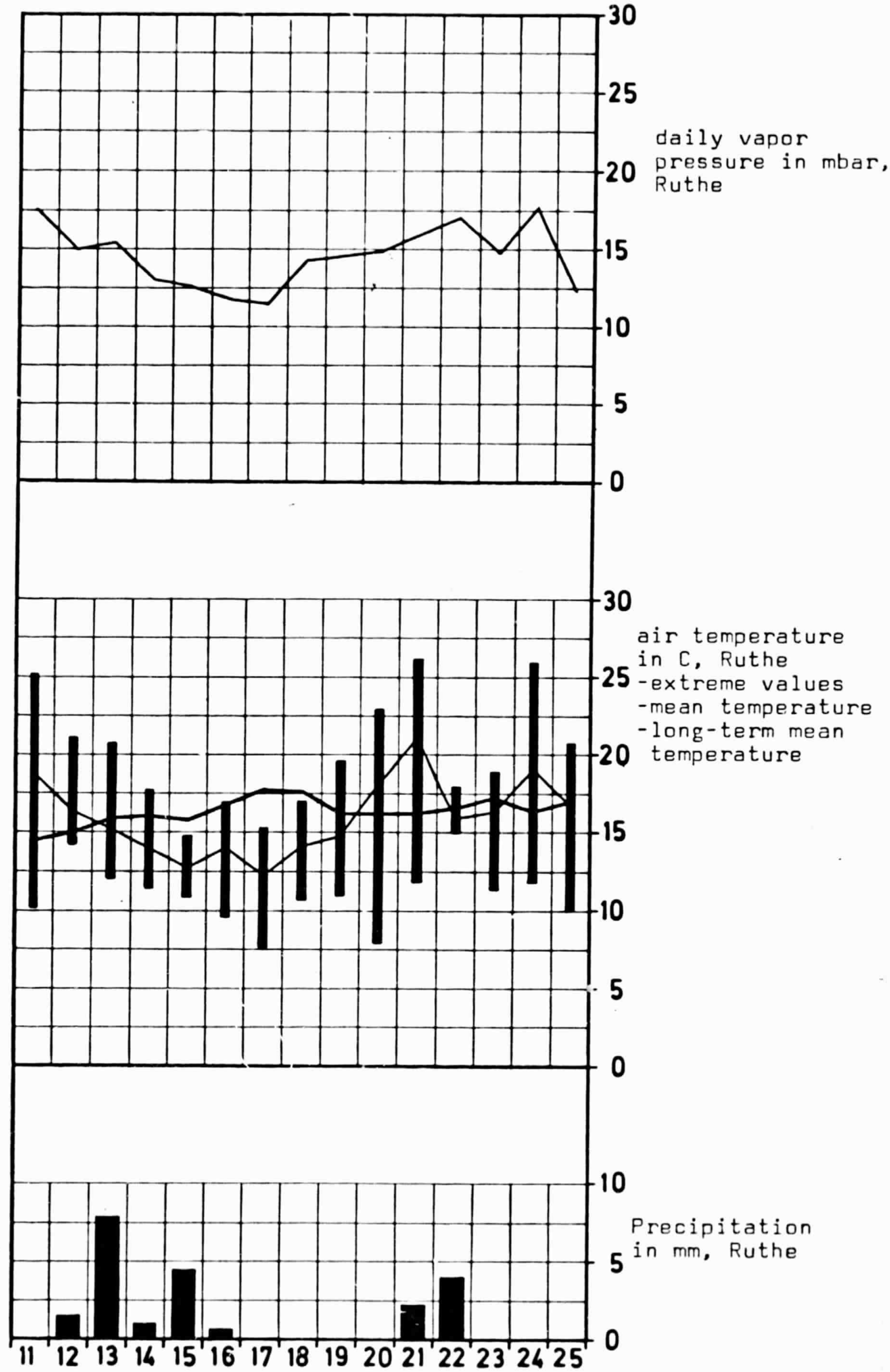


Fig. 4 .2.1 Sequence of weather from June 11th to June 25th, 1979

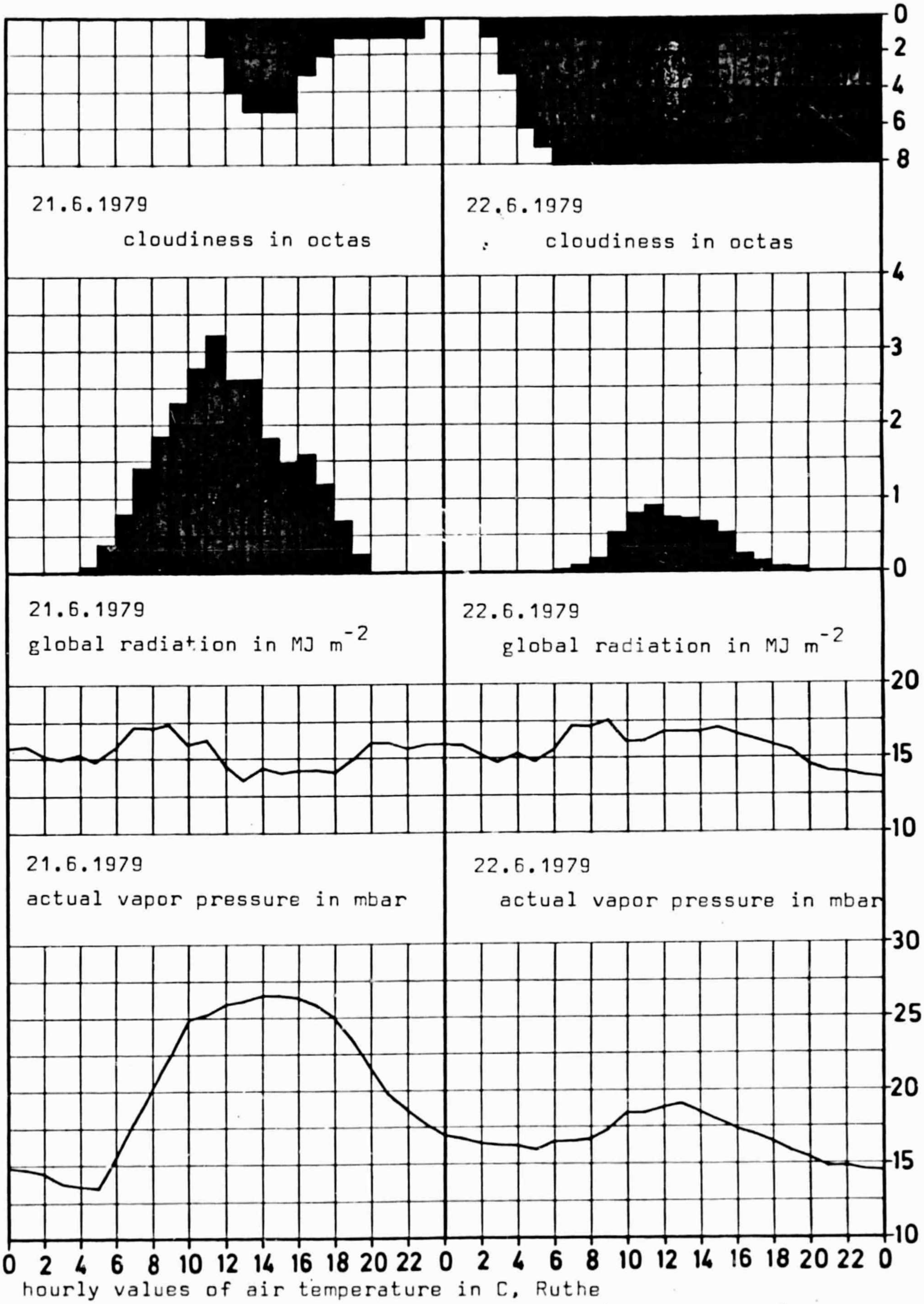


Fig.4 .2.2 Sequence of weather from June 21st to June 22nd, 1979

Fig. 4 .2.3 Weather Chart from June, 21st 1979

28-172 Donnerstag, 21.6.1979

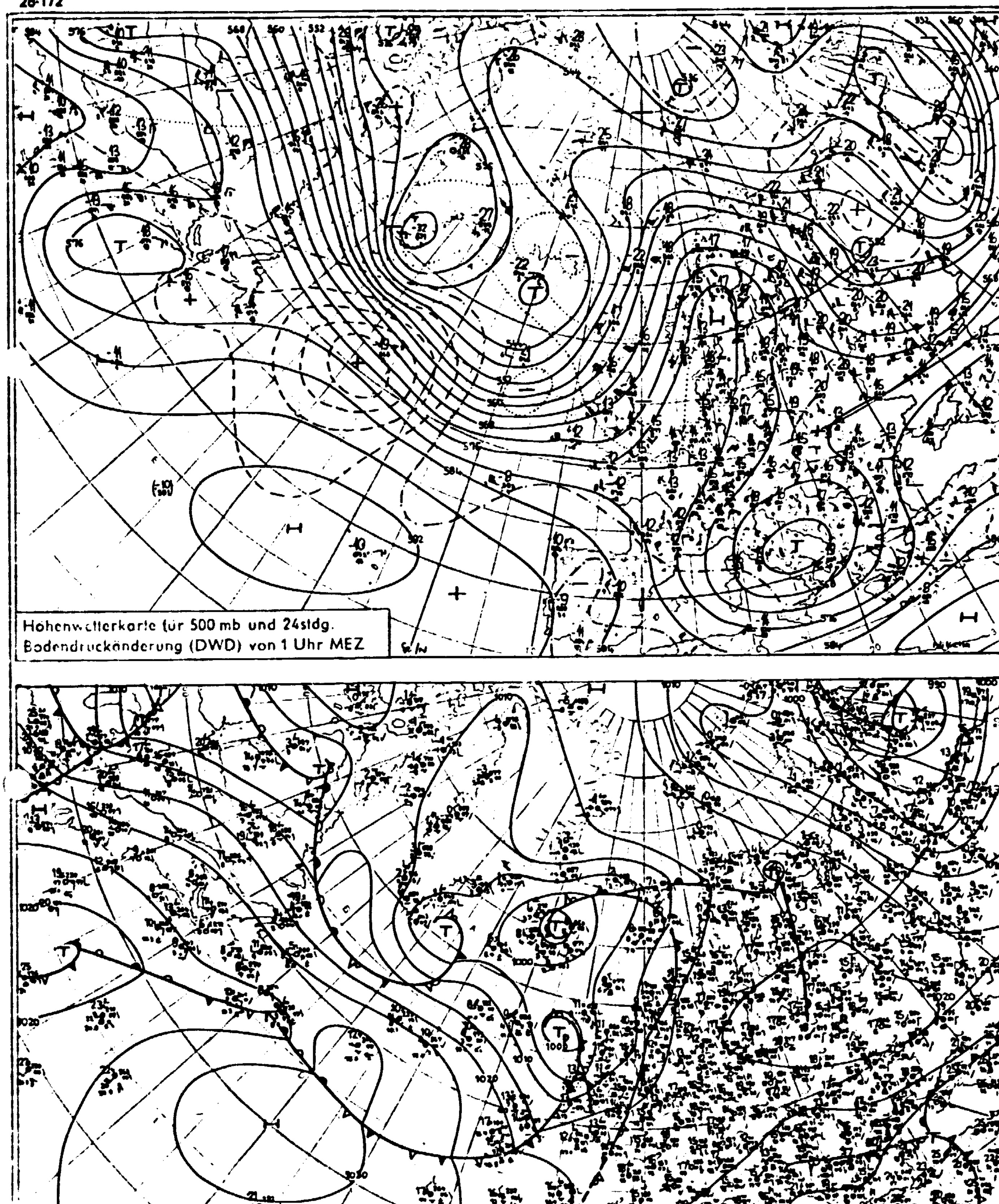


Fig. 4.2.4 Weather Chart from June, 22nd 1979

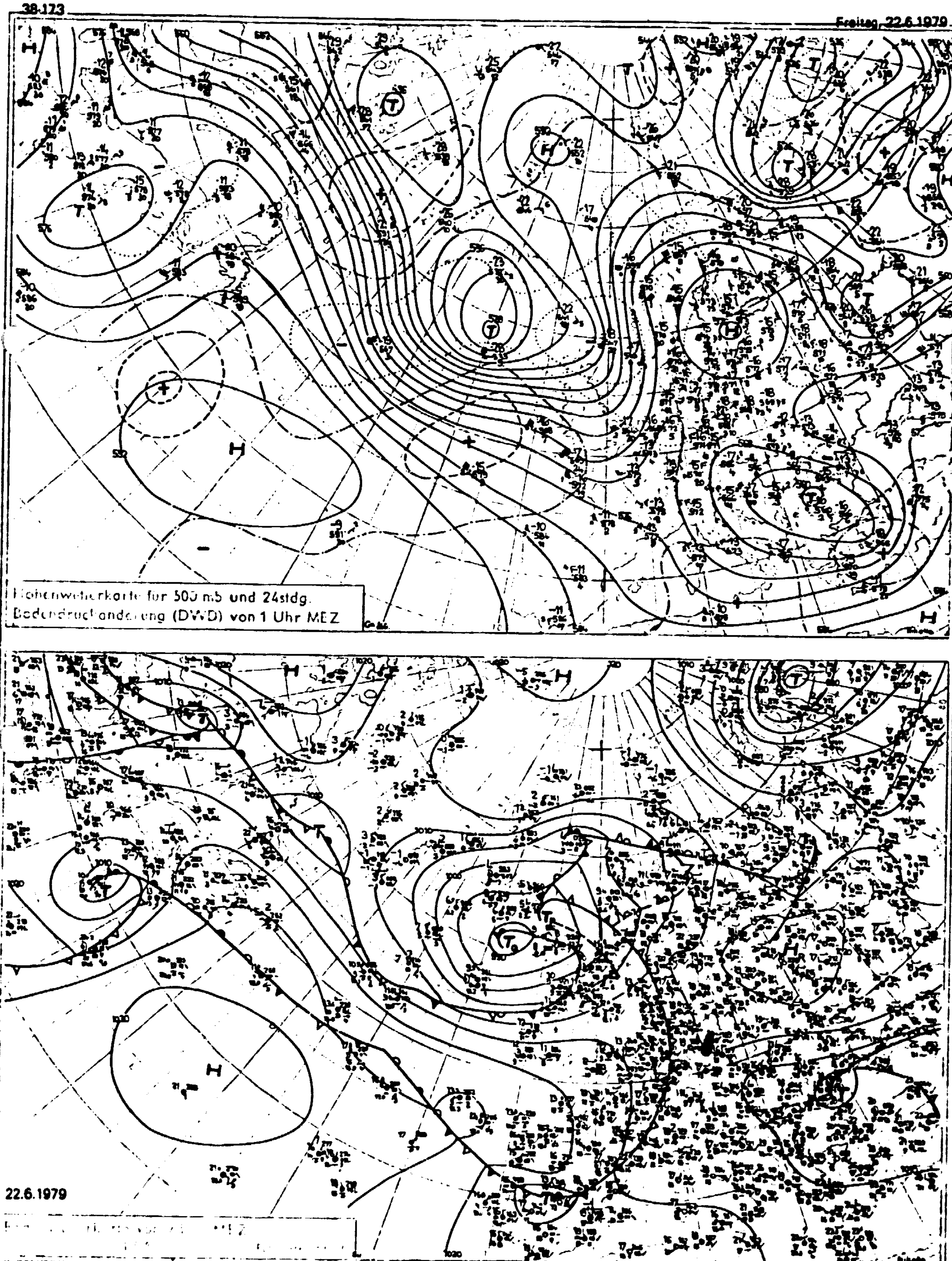
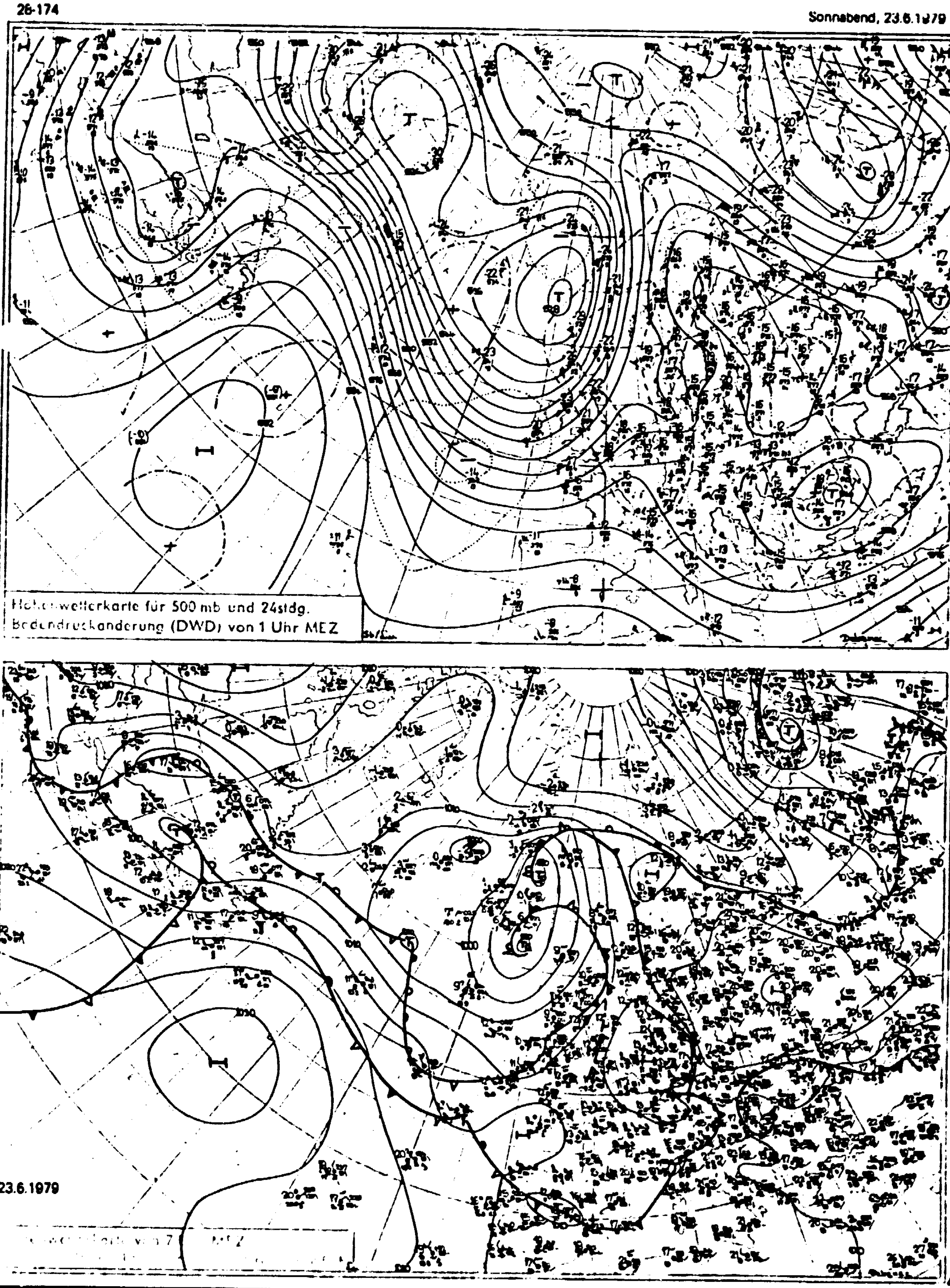


Fig. 4 .2.5 Weather Chart from June, 23rd 1979



5. Soil water studies during the JMC

R.R. van der Ploeg[1], A.B. Dua[1], O. Strebel[2] and M. Renger[3]

[1]Institut für Bodenkunde und Waldernährung der Universität Göttingen, [2]Bundesanstalt für Geowissenschaften und Rohstoffe and [3]Niedersächsisches Landesamt für Bodenforschung, Stilleweg 2, 3000 Hannover 51.

Introduction and objectives

During the Joint Measuring Campaign in Ruthe much effort was spent to collect soil water data. The water content of the soil was studied in two different ways. By means of gravimetric determinations the water content of the soil was determined directly. Indirect information about the water status of the soil was gained by means of tensiometer readings. With both methods soil water was studied on each of the seven different fields that were investigated during the Campaign.
With use of soil water data different components of the water budget equation can be derived. This equation can be written as

$$N = IET + V + \Delta R \quad , \tag{1}$$

in which expression N is the amount of rain during the period of study, IET the combined amount of evapotranspiration, V the amount of deep seepage, leaving the soil profile and ΔR the change in soil water storage.
Tensiometers, installed in different depths in the soil, provide for each depth a value of the matric potential. Denoting this matric potential with the symbol h, the total soil water potential H, can be calculated as

$$H = h - z \quad , \tag{2}$$

where z is the gravitational potential, determined as depth below some reference level, as the soil surface. Assuming a unique relation between the matric potential h and the soil water content θ, one cannot only use tensiometer readings to

calculate the potential distribution in the soil, but also to estimate the soil water distribution. Knowledge of the potential distribution enables one to decide (for one-dimensional soil water flow) whether the soil water movement is upward or downward. This information is especially useful if in some depth below the root zone a water divide or a zero-flux level ($\partial H/\partial z = 0$) can be detected. The total change in soil water content above the water divide can then be easily interpreted in terms of evapotranspiration; below the divide as deep seepage. It turned out that during the Campaign on all fields that were investigated such a water divide could be observed. As a consequence the tensiometer readings were very useful for the determination of the components of eq. 1.

In combination with tensiometer readings, gravimetric soil water determinations can also be used to estimate IET, V and ΔR of eq. 1, especially when a water divide below the root zone can be observed in the soil profile. If no water divide in the profile can be detected it is necessary to have knowledge of the hydraulic conductivity of the soil. The amount of seepage V, leaving the soil profile must then be calculated with Darcy's law:

$$V = -k(\partial H/\partial z)\Delta t \quad , \qquad (3)$$

in which expression k represent the hydraulic conductivity at the bottom of the soil profile, $\partial H/\partial z$ is the hydraulic gradient in the same depth, and Δt the time increment between two readings. Hence also the hydraulic properties of the soil profile (hydraulic conductivity and storage characteristics) must be known, if IET, V and ΔR from eq. 1 are determined with soil physics methods. A more detailed description of these methods may be found in the works of Richards et al. (1956), Ogata et al. (1960), Van Bavel et al. (1968a,b), Strebel et al. (1975) or Ehlers and Van der Ploeg (1976).

However, during the Campaign, soil water potential and soil water content determinations also served a different purpose. The soil water content or soil water potential enters models that describe the energy budget of a crop or the crop temperature, see Soer (1977a,b) or Nieuwenhuis and Klaassen (1978), and Klaassen and Nieuwenhuis (1978). Also in models that describe the water and heat exchange between a bare soil and the atmosphere, knowledge

of the water content of the surface layers of the soil is indispensable, see Rosema (1975). On the other hand crop temperatures or soil surface temperatures, as obtained by remote sensing, can be used to estimate the water content in the root zone of a crop or in the surface layers of a fallow soil, also by means of models. Measured soil water data can be compared with calculated soil water data to evaluate such models and the use of remotely sensed data for water budget evaluations. For this reason the soil water studies made in Ruthe constitute an essential part of the Joint Measuring Campaign.

Methods and materials

Gravimetric soil water determinations in Ruthe were made between June 6 and June 22. On Fields 1,2,3 and 4 the sampling started on June 6, on the Fields 5,6 and 7 on June 8. Every second day samples were taken from each of the seven fields that were studied during the Campaign. At the beginning of the Campaign an area of about 15 x 15 m was marked with stakes and tape on each of the 7 fields. In the middle of each 15 x 15 m plot was a row of 24 tensiometers that will be described in the next section. The samples taken for the gravimetric soil water determinations were always taken from these tensiometer plots. These plots in turn were adjacent to the micrometeorological instrumental plots.

The square areas of 15 x 15 m were subdivided into 4 equally sized subsquares. During the collection of soil samples on one field an equal number of samples was taken from each of these subsquares. During the beginning of the Campaign samples were taken in de corners of the 15 x 15 m plot. Every next time samples were taken, the sampled locations moved diagonally inwards toward the center of the field and towards the middle of the tensiometer row. Fig. 1 shows schematically the configuration of tensiometers and sample points during the Campaign.

Each time samples were taken from 17 depths: 0-2.5, 2.5-5.0, 5-10, 10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70-80, 80-90, 90-100, 100-110, 110-120, 120-130, 130-140, and 140-150 cm.

Of each depth there were 4 replicates arranged in a way as shown in Fig. 1. The sampling was done in 3 stages: from 0-10 cm, from 10-100 cm and from 100-150 cm, each time with a different type of auger. The augers were driven into the soil with a plastic hammer. The soil core obtained with each auger type was subsequently sectioned, according to the depths that were mentioned before. From each depth between 10 and 50 g of wet soil was put in a plastic cup. In the laboratory in Göttingen the samples were weighted and ovendried (105°C), in order to determine the water content by weight. For each depth the water content was taken as the arithmetic mean of 4 replicates.

On each of the seven fields, on which water and energy studies were conducted during the Campaign, tensiometers had been installed some time before the beginning of the Campaign. The experimental set-up on each of the 7 fields was the same. On each site 24 mercury-type tensiometers were installed in one row. They were located in 8 different depths (10,25,45,65,90,12o, 150 and 180 cm). In each depth there were 3 replicates. The total length of a row was less than 10 m. The tensiometer row was always between two plant rows (parallel). On Fig. 1 a schematic representation of a tensiometer field is shown. As mentioned previously, these tensiometer fields were close to the locations were agrometeorological measurements were taken. The tensiometers were read off once a day, usually in the morning. They were checked daily and, if needed, repaired or replaced. At the end of the Campaign the tensiometers in the upper layers of the wheat and barley fields stopped functioning because of soil dryness. Where they did not stop functioning, matric potential values less than - 600 cm water need to be treated with care. Such values may or may not be reliable.

The entire test site, and also the surroundings are located in a loess area. The loess layer is about 1.50 m thick and overlies sand deposits. The soil development as well as the physical properties of the loess layer are considered to be rather homogeneous throughout the area. Considering this spatial homogenity it seems justified to adopt for the soils of the Campaign test site the hydraulic properties as determined near Ahrbergen, which is located outside the test area. The properties were

determined by the Bundesanstalt für Geowissenschaften und Rohstoffe prior to the Joint Measuring Campaign. Nevertheless it was decided to take samples on Fields 1,2,3,4 and 6 to determine the retention characteristics and the conductivity relations. A comparison of the newly determined soil parameters with the ones previously determined for the soil of Ahrbergen showed indeed a close resemblance, especially for the upper 60 cm of soil. It was therefore decided to adapt the Ahrbergen data for the soils of the Campaign test site. They will be presented in the next section. However, for Field Nr. 1 (10-15, 40-45, 70-75, 107-112 and 160-170 cm), Field Nr. 2 (5-10, 35-40, 60-65, 110-115 and 160-165 cm), Field Nr. 3 (5-10), 30-35, 50-55, 90-95 and 130-135 cm), Field Nr. 4 (5-10), 35-40, 58-63, 95-100, 120-125 and 160-165 cm) and Field Nr. 6 (5-10, 35-40, 65-70, 85-90 and 120-125 cm) additional samples were analyzed to determine the hydraulic properties of the various horizons. Also for all these depths particle size distributions were determined. In the next section some results will be shown.

Results

Tables 1-7 show the tensiometer values (suction in cm water) as collected during the course of the experiment. Values over 600 cm need to be treated with some suspicion. It also needs to be remarked that per depth the dispersion in suction values, especially in the upper layers of Fields 3 and 4 was rather large. Tables 8-14 give an impression about the gravimetric soil water determinations, made during the course of the Campaign.
The values shown are not corrected. Hence they may contain sampling errors, weighing errors or other mistakes. The variation among the replicates is, for all depths, usually much larger as compared to the tensiometer values.
In Tables 15 and 16 the soil water retention and the hydraulic

conductivity relations (for the layers 0-60, 60-110, 110-150, 150-170 and 170-200 cm), as determined for Ahrbergen, are shown. The first 150 cm is loess material; below 150 one finds sand or gravel deposits.

For comparison Fig. 2 is shown. It shows the soil water retention curve for the layer 0-60 cm from Ahrbergen, and the same curve for the depths 10-15 and 40-45 cm of Field Nr. 1 (bare soil). One can see the close resemblance. Also shown are field-determined (tensiometer values - gravimetric soil water contents) water retention data, for the depths 20-30 cm and 40-50 cm, also for Field 1. These data points show that the laboratory-determined retention curves are in accordance with field values. Finally Table 17 is shown. It gives bulk density values determined for the soil profiles of Fields 1,2,3,4 and 6. These values can be used to convert soil water contents by weight, θ_w into soil water contents by volume, θ_v.

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LEGEND TO FIGURES AND TABLES OF CHAPTER 5

Fig. 1. Schematically representation of one tensiometer field, from which also every second day soil sample for water content determinations were taken.

Table 1. Tensiometer values (in cm water column), during the joint Measuring Campaign on Field Nr. 1 (bare plot).

Table 2. As for Table 1, but for Field Nr. 2 (Sugar beets).

Table 3. As for Table 1, but for Field Nr. 3 (Barley).

Table 4. As for Table 1, but for Field Nr. 4 (Wheat).

Table 5. As for Table 1, but for Field Nr. 5 (Sugar beets).

Table 6. As for Table 1, but for Field Nr. 6 (Barley).

Table 7. As for Table 1, but for Field Nr. 7 (Wheat).

Table 8. Soil water content (in l/m^2 per depth increment), as determined gravimetrically on Field Nr. 1 during the Joint Measuring Campaign.

Table 9. Same as in Table 8, however for Field Nr. 2 (Sugar beets).

Table 10. Same as in Table 8, however for Field Nr. 3 (Barley)

Table 11. Same as in Table 8, however for Field Nr. 4 (Wheat)

Table 12. Same as in Table 8, however for Field Nr. 5 (Sugar beets).

Table 13. Same as in Table 8, however for Field Nr. 6 (Barley)

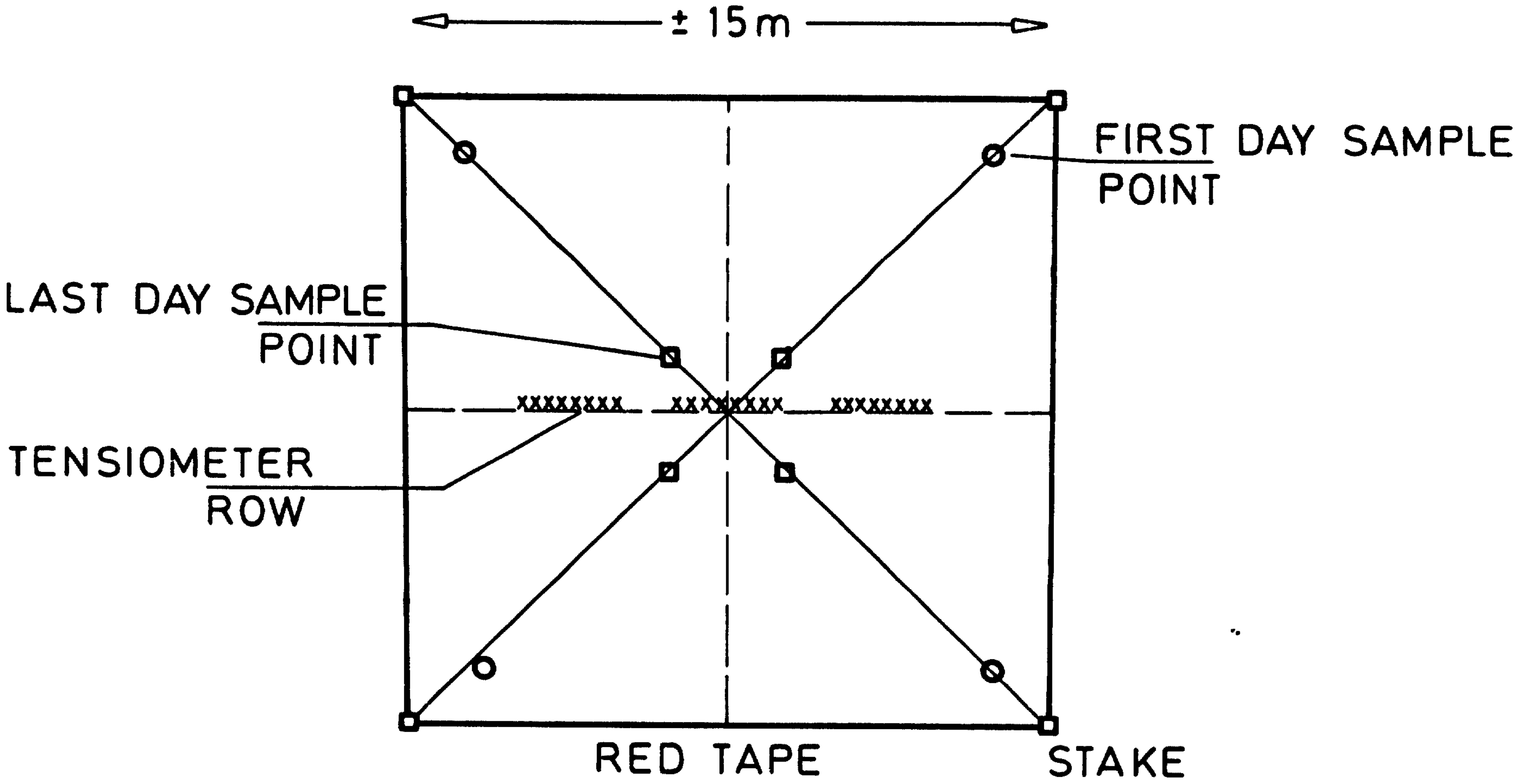
Table 14. Same as in Table 8, however for Field Nr. 7 (Wheat)

Table 15. Soil water retention relation for a layered loess soil of Ahrbergen (across the Leine River near Sarstedt)

Table 16. Hydraulic conductivity relations for a layered loess soil of Ahrbergen.

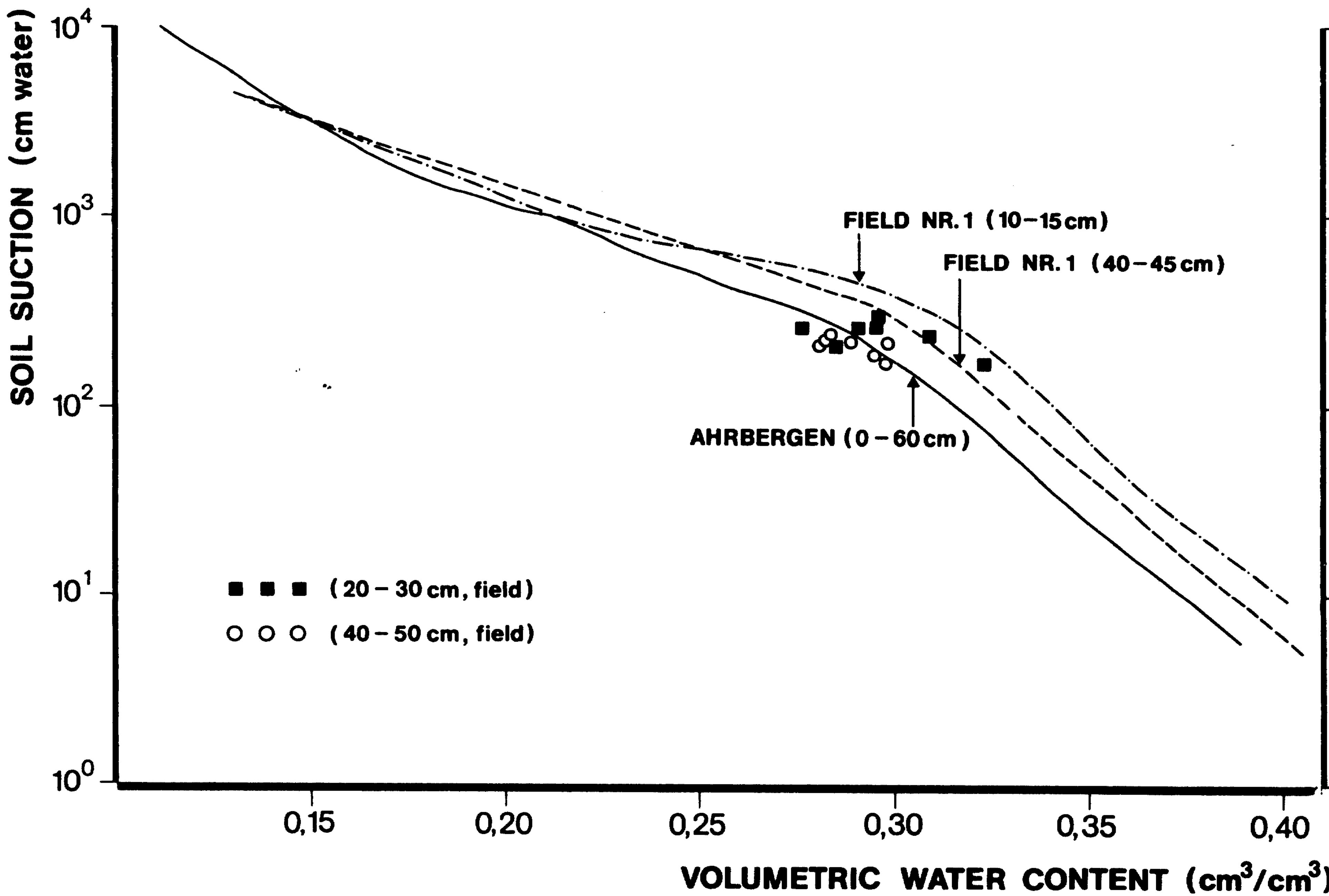
Fig. 2. Soil water relation curve for the 0-60 cm layer of the loess soil of Ahrbergen (Table 15), as compared with the curves from Field Nr. 1 (10-15 and 40-45 cm depth), and field-determined retention data (20-30 and 40-50 cm).

Table 17. Bulk density values for Fields Nr. 1,2,3,4 and 6. Numbers in parentheses indicate the depths from which samples were taken.



SCHEMATIC REPRESENTATION OF THE SITE FROM WHICH SOIL SAMPLES WERE TAKEN FOR GRAVIMETRIC SOIL WATER DETERMINATIONS

Fig. 5.1


SOIL SUCTION (cm water)
10^4
10^3
10^2
10^1
10^0
FIELD NR.1 (10–15 cm)
FIELD NR.1 (40–45 cm)
AHRBERGEN (0 – 60 cm)
■ ■ ■ (20 – 30 cm, field)
○ ○ ○ (40 – 50 cm, field)
0,15
0,20
0,25
0,30
0,35
0,40
VOLUMETRIC WATER CONTENT (cm³/cm³)

DAY	HOUR	DEPTH (cm)							
		10	25	45	65	90	120	150	180
7 - 6 - 79	12.15	295	252	208	188	127	110	104	
8 - 6	10.30	201	241	209	192	132	113	105	85
10 - 6	9.30	243	220	192	179	139	120	109	87
11 - 6	10.30	308	251	205	183	141	119	110	80
12 - 6	15.30	341	267	216	194	144	124	115	83
13 - 6	1C.00	345	279	226	202	148	127	115	84
14 - 6	12.30	177	216	205	185	149	127	115	83
15 - 6	10.15	156	215	200	183	152	131	115	85
16 - 6	19.00	150	176	177	164	153	133	115	
17 - 6	18.30	206	188	173	159	152	133	117	83
18 - 6	10.30	247	212	178	162	152	136	120	84
19 - 6	17.10	286	238	199	180	152	135	119	86
20 - 6	20.00	352	266	218	198	156	135	121	88
21 - 6	10.30	359	286	229	204	156	136	121	87
22 - 6	9.30	350	300	237	.219	161	140	122	89

Talbe 5.1

DAY	HOUR	DEPTH (cm)							
		10	25	45	65	90	120	150	180
7-6-79	12.30	303	256	228	209	161	123	119	122
8-6	11.00	188	255	230	212	167	124	121	129
10-6	9.45	251	233	214	203	166	129	125	129
11-6	10.45	336	256	228	211	158	130	127	112
12-6	15.45	419	272	240	221	163	134	129	117
13-6	14.00	284	282	251	235	163	135	131	115
14-6	12.30	199	259	236	219	165	136	129	120
15-6	10.30	150	255	233	218	168	138	133	118
16-6	14.30	171	223	213	205	168	139	135	114
17-6	18.45	252	224	208	200	167	140	133	119
18-6	11.00	294	237	217	203	168	140	133	120
19-6	17.15	363	266	240	221	171	142	134	126
20-6	20.00	474	292	259	236	173	144	137	124
21-6	10.45	450	306	267	240	172	144	136	123
22-6	9.45	394	232	281	.250	177	148	138	124

Table 5.2

DAY	HOUR	DEPTH (cm)							
		10	25	45	65	90	120	150	180
7-6-79	12.50	495	434	355	225	157	108	75	52
8-6	11.15	363	481	356	229	156	110	75	53
10-6	11.00	408	404	365	238	163	112	78	54
11-6	17.00	504	504	373	246	169	115	79	39
12-6	14.30		523	393	240	171	116	79	43
13-6	9.30		525	421	246	172	119	82	45
14-6	12.30	359	516	415	246	171	118	87	45
15-6	10.00	337	516	423	251	173	118	84	47
16-6	19.45	316	401	414	253	173	123	83	47
17-6	19.00	387	501	420	258	177	125	84	47
18-6	11.00	421	501	431	261	178	124	85	43
19-6	17.25	530	530	416	263	180	126	86	46
20-6	20.15		574	458	270	182	127	88	49
21-6	16.45		593	431	273	187	129	88	50
22-6	10.00		601	466	.276	189	134	90	50

Table 5.3

DAY	HOUR	DEPTH (cm)							
		10	25	45	65	90	120	150	180
7-6-79	14.00	530	499	352	258	179	157	131	128
8-6	12.00	398	503	427	252	185	160	130	113
10-6	12.15	463		395	251	194	168	135	115
11-6	14.00	523	551	400	270	196	168	131	113
12-6	18.00	606	605	433	308	205	170	133	117
13-6	14.30	649	610	442	303	208	173	133	118
14-6	13.00	455	593	469	318	207	175	133	115
15-6	16.30	487	618	487	332	214	180	135	117
16-6	18.30	456	606	493	341	219	183	135	117
17-6	19.00	407	621	500	340	222	183	135	116
18-6	20.15	536	621	510	353	226	183	137	116
19-6	11.45	565		518	355	226	185	138	117
20-6	16.30			510	347	232	190	138	123
21-6	10.30			512	370	232	190	138	120
22-6	12.00			548	.386	241	197	141	122

Table 5.4

DAY	HOUR	DEPTH (cm)							
		10	25	45	65	90	120	150	180
7-6-79									
8-6	14.40	185	211	208	185	136	100	69	54
10-6	12.00	292	230	204	178	145	111	73	64
11-6	16.10	345	255	220	193	136	103	70	60
12-6	18.00	395	271	229	201	135	98	72	48
13-6	16.00	298	262	235	209	136	104	76	46
14-6	10.30	247	242	232	205	143	102	73	50
15-6	19.00	137	235	228	204	152	107	77	56
16-6									
17-6	19.50	280	224	206	178	138	102	76	46
18-6	18.40	340	254	222	195	149	110	77	68
19-6	19.30	379	270	235	207	146	106	77	62
20-6	7.45	393	285	244	218	163	114	79	71
21-6									
22-6	9.50	386	321	264	.232	156	113	79	57

Table 5.5

DAY	HOUR	DEPTH (cm)							
		10	25	45	65	90	120	150	180
7-6-79	14.30	329	243	215	162	103	30	-14	-43
8-6	14.15	290	238	213	163	104	28	-10	-41
10-6	12.30	268	244	224	169	114	39	- 4	-34
11-6	15.05	335	278	241	179	126	47	- 2	-31
12-6	18.30	355	288	245	178	121	41	- 2	-34
13-6	15.00	355	292	247	180	120	38	- 2	-36
14-6	10.00	278	282	248	186	123	45	- 2	-33
15-6	18.45	246	271	244	191	129	49	5	-26
16-6									
17-6	20.20	222	252	226	176	123	50	10	-24
18-6	18.05	316	264	240	183	129	60	12	-19
19-6	19.45	334	265	239	181	125	51	10	-23
20.6	6.45	353	279	257	201	141	65	12	-20
21-6									
22-6	12.35	418	334	275	.201	139	61	13	-18

Table 5.6

DAY	HOUR	DEPTH (cm)							
		10	25	45	65	90	120	150	180
7-6-79	14.00	279	243	208	176	97	43	14	-11
8-6	14.00	183	233	206	172	90	42	15	-12
10-6	12.35	284	267	224	185	112	58	25	2
11-6	15.25	359	289	237	193	111	57	26	2
12-6	18.15	436	302	247	194	109	57	27	0
13-6	15.00	280	312	262	206	120	63	30	9
14-6	10.00	245	287	253	207	125	70	31	7
15-6	18.30	228	285	258	206	123	70	35	12
16-6									
17-6	20.05	255	271	245	200	116	67	39	10
18-6	18.15	319	293	258	207	124	73	42	18
19-6	20.20	348	298	262	203	123	71	42	17
20-6	7.00	383	315	267	222	140	82	44	27
21-6									
22-6	11.15	454	358	292	227	134	80	44	22

Table 5.7

	TIME (DAY IN JUNE, 1979)								
DEPTH (cm)	6-6-79	8-6	10-6	12-6	14-6	16-6	18-6	20-6	22-6
0-2.5	6.60	6.71	4.40	2.81	6.35	6.95	5.24	3.49	6.71
2.5-5	5.91	6.87	5.89	5.36	6.55	6.95	6.45	5.70	6.30
5-10	10.45	13.49	12.76	12.22	13.35	14.38	13.22	12.76	12.65
10-20	29.67	26.56	26.60+	26.64	27.60	29.46	27.02	26.75	27.07
20-30	29.36	30.80	29.47	29.00	29.07	29.27+	28.43	27.44	27.50+
30-40	28.55	28.28	26.32	26.61	26.44	27.22	26.84	26.07	26.96
40-50	30.19	29.87	29.55	28.19	28.09	29.76	29.83	28.91	28.26
50-60	29.71	29.10	29.07	28.90	28.76	29.42	29.12	29.21	28.66
60-70	29.35	30.36	30.63	29.53	30.93	30.97	31.28	31.32	31.44
70-80	30.20	31.50	32.07	31.06	32.42	32.10	32.37	31.93	33.59
80-90	32.19	32.57	32.92	32.92	32.59	32.51	32.82	32.82	33.05
90-100	32.54	32.57	32.27	32.19	32.17	32.39	32.21	31.68	32.71
100-110	30.63	33.61	34.92	33.40	33.84	34.18	32.87	33.80	34.62
110-120	31.32	34.27	34.78	33.39	33.61	34.64	33.37	34.13	34.14
120-130	32.98	33.14	33.60	32.78	32.74	36.24	33.12	33.54	34.13
130-140	33.07	30.87	32.73	31.77	29.65	33.15	33.30	33.41	33.21
140-150	34.21	30.11	31.97	30.77	31.03	31.67	32.14	32.32	32.66

Table 5.8

T I M E (DAY IN JUNE, 1979)									
DEPTH (cm)	6-6-79	8-6	10-6	12-6	14-6	16-6	18-6	20-6	22-6
0-2.5	6.69	6.43	4.79	4.30	6.94	7.38	5.41	3.47	6.72
2.5-5	6.37	6.98	6.19	5.83	6.96	7.10	6.04	5.62	6.17
5-10	10.02+	14.23	13.39	12.29	13.93	14.05	13.10	12.42	13.08
10-20	28.15	29.64	28.71	28.49+	29.23	28.40	29.07	27.10	28.80
20-30	29.79	31.21	28.49	26.46	28.05	27.75	28.06	28.43	27.49
30-40	29.10	26.51	26.49	25.04	25.84	26.59	26.42	25.24	25.15
40-50	28.88	27.47	26.87	26.36	26.60	27.32	27.83	26.84	25.09
50-60	28.12	28.06	27.98	27.55	27.88	28.68	28.40	27.11	26.16
60-70	28.73	30.67	30.41	30.05	30.48	30.50	30.29	29.45	29.56
70-80	29.53	30.66	30.63	30.45	30.88	31.38	30.80	30.00	30.59
80-90	29.25	30.67	30.09	30.22	30.12	31.00	30.30	29.83	29.92
90-100	25.83	28.72	28.94	28.24	28.99	29.90	29.35	28.60	28.93
100-110	20.77	29.15	28.71	27.55	29.30	30.85	30.78	30.64	31.05
110-120	22.72	25.73	25.45	25.97	26.47	28.57	28.13	29.81	31.35
120-130	25.00	24.19	23.53	25.38	25.19	25.04	28.35	28.00	27.76
130-140	26.05	22.91	21.45	22.66	22.37	23.89	23.00	25.56	26.18
140-150	28.81	20.82	22.20	17.04	18.33	21.26	22.44	21.60	23.53

Table 5.9

	TIME (DAY IN JUNE, 1979)								
DEPTH (cm)	6-6-79	8-6	10-6	12-6	14-6	16-6	18-6	20-6	22-6
0-2.5		7.16	6.03	4.91	7.46	7.73	6.54	5.68	7.12
2.5-5		6.07	5.60	4.68	6.51	7.23	6.09	5.25	5.77
5-10		10.29	10.33	9.53	12.10	13.76	11.80	10.43	9.73
10-20		23.00	19.80	20.61	22.70	23.83	22.62	21.51	20.60
20-30		22.70	22.24	21.15	21.55+	21.95	23.51	22.32	21.13
30-40		23.09	22.27	21.40	22.82	22.72	22.86	23.34+	21.53
40-50		23.76	23.30	22.64	23.85	24.34	23.73	23.46+	21.85
50-60		28.48	27.63	26.47	26.63	27.19	26.05	26.26+	25.99
60-70		29.15	28.88	27.91	28.52	28.32	27.34	27.82+	26.94
70-80		29.50	29.20	28.98	29.45	28.83	27.97	27.80	27.48
80-90		31.26	31.15	31.88	30.91	31.41	30.38	30.79	29.79
90-100		31.12	29.63	30.46	30.54	30.17	30.63	30.16	29.68
100-110		30.93	29.80	27.66	29.86	29.08	29.62	29.66	28.73
110-120		29.93	29.56	28.47	30.37	28.66	29.20	29.70	28.22
120-130		26.98	28.17	24.42	27.38	26.95	25.65	26.66	26.14
130-140		24.52	26.88	24.48	25.07	20.20	19.80	24.96	22.85
140-150		17.80	18.66	18.06	22.69	12.92	13.89	18.15	14.63

Table 5.10

TIME (DAY IN JUNE, 1979)									
DEPTH (cm)	6-6-79	8-6	10-6	12-6	14-6	16-6	18-6	20-6	22-6
0-2.5		5.77	4.63	3.88	5.39	5.25	4.51	3.63	5.64
2.5-5		5.07	4.51	3.86	5.08	5.07	4.45	3.76	4.78
5-10		8.50	8.81	7.61	9.00	9.21	8.42	7.24	7.80
10-20		15.89	16.23^{+}	16.56	17.27	16.07	15.59	15.28	15.63
20-30		18.15	18.01^{+}	18.37	18.20	17.02	16.36	17.37	16.07
30-40		21.20	20.26^{+}	21.03	19.09	17.39	18.28	16.75	17.45
40-50		22.09	21.68	21.35^{+}	21.01	20.36	19.74	19.71	17.01
50-60		26.42^{+}	26.19	26.42^{+}	27.97	28.15	26.61^{+}	26.60	24.84^{+}
60-70		29.72^{+}	30.00	30.44	30.04	28.49	28.51	28.80	28.29^{+}
70-80		29.72	30.29	31.90	29.44	28.91	28.99	29.41	28.29
80-90		30.16	30.44	30.32	29.30	28.97	29.71	29.39	28.95
90-100		31.10	31.62	31.14	30.70.	31.95	30.78	31.23	29.70
100-110		30.01	31.27	30.65	31.66	31.12	31.32	29.40	30.38
110-120		30.49	31.57	30.75	31.10	30.75	30.51	29.69	30.50
120-130		31.57	31.20	30.96	30.08	30.53	29.56	30.32	30.08
130-140		30.59	30.19	30.80	28.66	30.01	28.28	29.05	30.40
140-150		31.05	31.40	32.87	29.23	29.65	27.72	28.94	28.94

Table 5.11

	TIME (DAY IN JUNE, 1979)								
DEPTH (cm)	6-6-79	8-6	10-6	12-6	14-6	16-6	18-6	20-6	22-6
0-2.5		6.46	5.31	3.99	5.65	6.79	5.69	3.95	7.16
2.5-5		6.86	6.78	6.37	6.66	7.09	6.41	5.37	6.89
5-10		13.53	13.50	13.37	13.37	14.32	13.53	12.58	13.43
10-20		25.05	24.71	26.05	24.44	26.55	25.57	24.08	23.90
20-30		25.79	26.58	25.56	24.85	25.43	25.71	24.15	25.04
30-40		30.03	29.91	27.03	27.25	27.38	26.86	25.77	26.72
40-50		28.89	29.12	28.15	27.93	28.19	26.95	27.57	26.83
50-60		27.71	29.03	28.94	28.14	28.15	27.83	28.00	26.77
60-70		28.14	28.89	28.99	27.90	27.64	28.23	28.40	27.22
70-80		29.22	31.89	30.89	28.42	28.31	28.05	29.21	28.77
80-90		30.97	31.75	30.71	28.31	30.22	29.30	30.46	30.07
90-100		28.88	27.92	29.15	28.78	29.73	27.78	29.44	30.42
100-110		30.27	28.14	31.64	28.66	30.50	27.02	26.72	28.37
110-120		31.92	31.76	31.04	30.85	28.66	28.13	27.43	30.05
120-130		28.54	30.77	30.36	30.44	30.38	29.50	28.29	29.02
130-140		27.35	29.07	28.46	25.68	28.01	28.59	27.72	27.23
140-150		23.43	26.37	25.80	26.50	26.21	26.54	27.10	28.45

Table 5.12

DEPTH (cm)	6.6.79	8-6	10-6	12-6	14-6	16-6	18-6	20-6	22-6
				TIME (DAY IN JUNE, 1979)					
0-2.5		7.92	6.99	6.79	7.74	7.59	6.81	6.42	7.50
2.5-5		7.39	6.44	6.22	7.41	7.24	6.55	6.22	6.94
5-10		13.60	12.65	12.37	14.25	14.31	12.89	12.41	12.66
10-20		26.03	27.09	26.70	27.82	27.38	27.56	26.60	24.88
20-30		26.69	28.65	27.10	27.16	26.53	27.32	26.28	25.57
30-40		29.93	30.50	29.99	29.94	29.40	30.41	29.15	28.91
40-50		31.46	30.94	31.05	30.88	31.29	30.20	30.81	30.61
50-60		31.47	31.40	32.35	32.19	31.98	31.28	31.63	31.07
60-70		32.58	31.75	32.73	33.53	3[illegible].32	31.52	31.74	31.53
70-80		32.86	32.16	33.80	33.69	32.75	32.11	31.16	32.20
80-90		30.67	31.69	31.12	30.93	29.48	29.80	29.79	31.48
90-100		27.34	30.18	28.20	28.24	28.58	27.74	28.47	29.84
100-110		31.38	31.56	30.93	31.70	31.04	30.88	30.54	32.29
110-120		31.00	31.48	31.14	31.33	30.96	30.90	31.40	31.11
120-130		32.65	32.11	31.68	31.51	30.70	30.97	33.56	31.45
130-140		33.79	33.36	33.02	32.43	32.22	31.67	32.13	32.13
140-150		36.29	32.56	34.32	35.46	33.62	32.65	33.52	33.36

Table 5.13

	T I M E (DAY IN JUNE, 1979)								
DEPTH (cm)	6-6-79	8-6	10-6	12-6	14-6	16-6	18-6	20-6	22-6
0-2.5		7.76	6.58	5.95	6.98	7.74	6.80	6.00	6.79
2.5-5		7.34	6.50	5.79	6.82	7.36	6.63	5.78	6.16
5-10		14.28	12.62	11.69	12.85	13.79	12.79	11.54	12.73
10-20		26.69	25.28	24.59	23.85	25.56	24.92	22.09	23.48
20-30		25.69	26.32	24.65	24.44	24.70	25.04	24.40	23.31
30-40		28.98	27.79	27.77	27.21	27.57	27.67	25.89	26.27
40-50		29.35	29.30	28.08	27.75	27.20	27.44	26.07	28.11
50-60		29.57	29.08	28.18	28.35	20.31	27.44	27.18	28.64
60-70		30.32	29.78	29.86	29.72	28.47	27.86	28.07	28.87
70-80		30.13	30.34	30.77	30.43	30.00	29.25	29.93	29.89
80-90		30.03	28.93	29.26	30.08	29.80	29.27	29.73	30.05
90-100		29.11	28.79	28.57	29.34	28.71	28.09	28.74	31.22
100-110		32.67	31.00	31.57	32.38	31.52	31.29	30.07	32.19
110-120		32.49	31.28	31.73	32.68	32.69	31.05	30.24	31.07
120-130		32.52	32.61	31.21	32.39	32.60	31.16	30.48	29.69
130-140		30.58	31.96	29.80	31.72	31.45	30.94	30.43	28.94
140-150		28.77	30.53	29.88	30.93	28.58	29.50	30.25	29.14

Table 5.14

soil suction (cm H_2O)	volumetric moisture content				
	depth				
	0-60 cm	60-110	110-150	150-170	170 cm
0	.430	.410	.380	.370	.370
10	.380	.390	.354	.280	.270
20	.356	.378	.340	.240	.210
40	.336	.366	.328	.210	.150
60	.328	.357	.323	.190	.120
100	.316	.342	.320	.165	.110
200	.295	.322	.312	.136	.097
400	.260	.302	.291	.112	.087
600	.234	.290	.276	.102	.082
1000	.200	.280	.250	.092	.077
2000	.167	.270	.202	.080	.072
4000	.140	.252	.174	.070	.067
6000	.128	.240	.162	.062	.060
10000	.110	.222	.150	.056	.052
20000	.095	.200	.130	.051	.045
40000	.081	.180	.114	.049	.040
60000	.074	.170	.104	.047	.035

Table 5.15

volum. moisture content	hydraulic conductivity (cm/day) depth				
	0-60 cm	60-110	110-150	150-170	170 cm
0.43	.25E+03				
0.41	.11E+03	.80E+02			
0.39	.40E+02	.10E+02			
0.37	.30E+01	.40E+00	.40E+01	.10E+02	.10E+04
0.34	.50E+00	.10E-01	.30E+00	.80E+01	.50E+03
0.31	.20E-01	.20E-03	.60E-03	.61E+01	.10E+03
0.28	.24E-02	.50E-05	.10E-04	.38E+01	.40E+02
0.25	.45E-03	.30E-06	.30E-06	.13E+01	.21E+02
0.22	.70E-04	.10E-07	.10E-07	.18E+00	.50E+01
0.19	.10E-04	.30E-09	.30E-09	.10E-01	.14E-01
0.16	.15E-05	.10E-10	.10E-10	.40E-03	.12E+00
0.13	.30E-06	.30E-12	.30E-12	.90E-05	.66E-02
0.10	.12E-07	.10E-13	.10E-13	.50E-07	.16E-04
0.07	.45E-09	.30E-15	.30E-15	.10E-07	.30E-05

Table 5.16

FIELD NUMBER				
1	2	3	4	6
(10-15)	(5-10)	(5-10)	(5-10)	(5-10)
1.38	1.56	1.23	1.55	1.35
(40-45)	(35-40)	(30-35)	(35-40)	(35-40)
1.49	1.39	1.62	1.44	1.49
(70-75)	(60-65)	(50-55)	(58-63)	(65-70)
1.53	1.46	1.46	1.48	1.46
(107-112)	(110-115)	(90-95)	(95-100)	(85-90)
1.65	1.62	1.59	1.59	1.63
(160-170)	(160-165)	(130-135)	(120-125)	(120-125)
1.69	1.65	1.76	1.55	1.65

Table 5.17

6. Radiosonde Measurements

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6.1 Radiosonde stations

During the Tellus JMC from June 11th, 1979 to June 22nd, 1979 radiosonde measurements were carried through at the Weather Bureau at Hanover-Langenhagen. The radiosonde station is located approximately 9 km north of the city of Hanover at the airport (cf. Fig. 4.1). The test site for JMC was situated near the village of Ruthe 16 km south of Hanover, so there existed a total distance of 25 km between the radiosonde station and the test site. The geographical situation may be taken from the attached map which shows the environment of Hannover (Fig. 4.1).

The radiosonde data were needed for the atmospheric correction of measurements made by an airborne scanning radiometer. When choosing the test site near Ruthe the possibility to perform radiosonde measurements at the weather bureau at Hanover-Langenhagen proved as a very favorable circumstance. This can be understood when the fragmentary net of radiosonde stations is taken into consideration. Except for Hanover the nearest radiosonde station would be in Essen 220 km southwest of the test site. At this point the similarity of the surface characteristics of both places should be emphasized. The test site as well as the radiosonde station is situated in a flat area with a high ground water table in only 1 to 3 m depth. The region of Hanover shows extensive agricultural use whereas the environments of the radiosonde station is more dominated by grassland and patches of forest. In this area north of Hanover the ground water table is found to be somewhat higher than in the south of the city. This fact is given evidence by the occurrence of swamps only 4 km north

of the radiosonde station.

In the lowest 1000 to 1500m of the atmosphere temperature and water vapor content are highly influenced by the type of underground. A realistic correction of the atmospheric modifications upon the scanner measurements requires an exact determination of parameters such as temperature, air pressure and water vapor content mainly in the planetary boundary layer. Therefore taking data from a nearby radiosonde station is always a more or less rough approach to the real vertical profile of the atmospheric parameters in question for the test site. In the case mentioned however a reasonable good approximation of the atmospheric constitution at the test site by radiosonde data might be expected because of the similar surface properties at both places. This statement is not valid for the ground measurements since the radiosonde is started over a concrete area.

At the Hanover radiosonde station routine soundings of vertical distribution of air pressure, temperature and relative humidity are made at 12 GMT and 00 GMT each day. The actual data of these measurements can be found in the " Europäischer Wetterbericht" (European Weather Report), a current publication of the German Weather Service. In addition to these measurements the balloon can be traced by a radar device which the elevation, azimuth and horizontal distance of the balloon from the radiosonde station is determined. The comparison of these data and the time between two radar measurements gives the direction and the speed of the wind. With the help of the time-height curve which is drawn into the thermodynamical paper the wind vector can be attached to the appropriate level. At 6 GMT and 18 GMT only wind measurements are performed (Hesse, 1961).

6.2 Accuracy of equipment

In Germany the M60 radiosonde is used for routine soundings

The sensors for pressure, temperature and relative humidity control the position of contact pointers which are scanned by a rotating Morse drum. The Morse signals are transmitted to the ground station by a small sender. The temperature is measures by a bimetal whereas pressure is registered by an aneroid barometer and relative humidity by rolled Pernix hair. In the following the reliability of the employed instruments shall be discussed briefly.

All sensors are calibrated isolated from each other under laboratory conditions. Therefore each radiosonde possesses a calibration sheet. The behaviour of the sensors in a radiosonde cannot be investigated by such a calibration. For this purpose radiosonde ascents together with precision sondes are carried through. By comparion of the data one can receive the magnitude of the deviations. Fig. 6.1 shows the differences in temperature between the M60 sonde and the precision sonde. The data of the M60 are corrected only for the time lag of the bimetal. The radiative falsification was not taken into consideration for the M60.

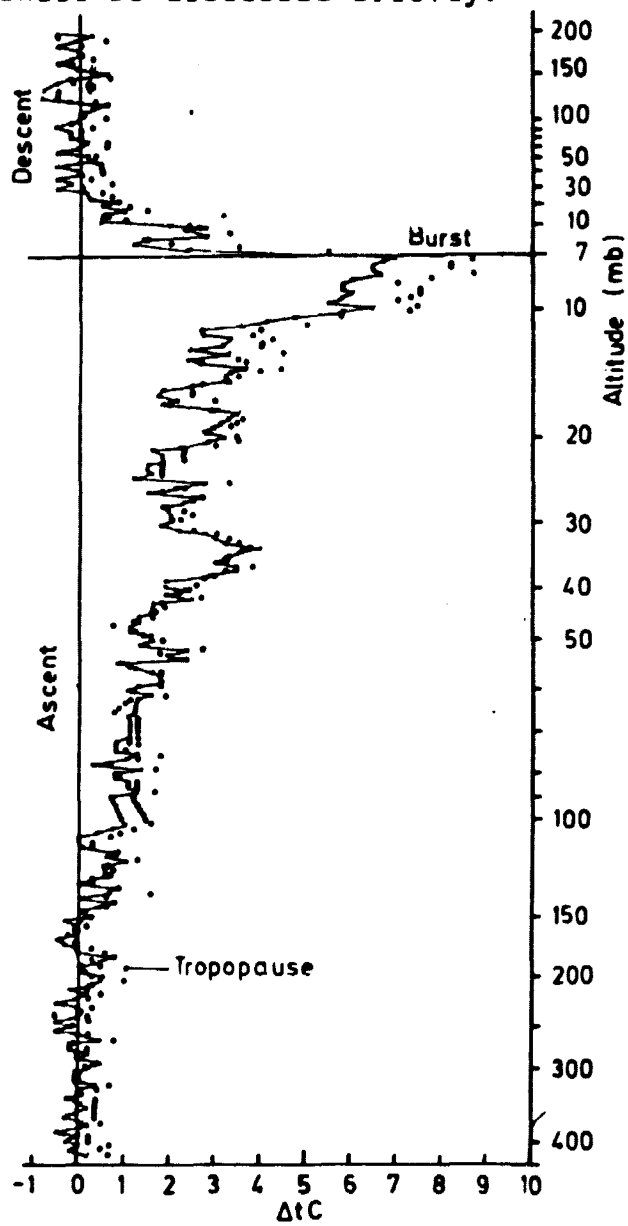


Fig. 6.1: Differences in temperature between the M60 sonde and the precision sonde

As can be taken from Fig. 6.1 the temperature deviation of the M60 from the precision does not exceed 1 K up to 100 mbar. For pressures less than 100mbar the temperature deviation increases and reaches its maximum values at the 10 mbar level. Synchronous ascents of the precision sonde with the M60 sonde yielded an average difference in pressure (precision sonde minus M60) of 1.57 mbar between 960 mbar and 20 mbar.

Before each radiosounding the radiosonde is calibrated at the ground station. A deviation of 2 Morse signals from the values in the appropiate calibration sheet is still tolerated. This means an inaccuracy of 0.5 K in temperature, 5 mbar in pressure and 2% in relative humidity. Unfortunately more evident when considering the extreme conditions which are encountered by the radiosonde during the soundings. Temperatures can vary over a range of 100 K. Variations in pressure and relative humidity can amount up to 1000 mbar and about 100 % respectively. The accuracy of radiosonde measurements is a function of height with the tendency towards more inaccurate values with increasing height.

In the cases of temperature measurements this circumstance has been shown in Fig. 6.1 . The most unreliable values gives the measurement of relative humidity. Especially below the freezing point the accuracy of relative humidity values decreases with decreasing temperatures. Below -10^{o}C deviations of 10% and more might occur. The radiative falsification of temperature measurements is another contribution to inaccuracy which is not completely solved. For this reason each radiosonde bears a hollow cylinder out of aluminium around the in-truments to protect them against direct solar radiation. The cylinder is open at both ends to assure a sufficient ventilaton of the sensors. Since the radiosonde is swinging more or less it cannot be

prevented that the instruments are hit occasionally by direct solar radiation especially at high elevations of the sun.

Because of their inertia the instruments do not measure the real values of pressure, temperature and relative humidity. The principal deviations from reality shall be shown by consideration of idealized transition in temperature sensors. For simplification a laminar airflow and radiative balance between the thermometer and its environment are presumed. If T_L is the true air temperature, T the measured air temperature and α the inertia value in s then the difference between true an measured temperature can be written as:

$$T_L - T = \alpha \cdot dT/dt \qquad (6.1)$$

All temperatures are given in Kelvin. t is defined as the time in s . Furtheron γ stands for the vertical temperature gradient in K/s (i.e. the gradient that is encountered by radiosonde due to its climbing speed). For the true temperature at the time t one gets:

$$T_L = T_{L_0} - \gamma t \qquad (6.2)$$

T_{L_0} is defined as the temperature at the time t = 0. Substituting equation (6.2) into equation (6.1) and solving the resulting differential equation gives:

$$T = (T_0 - T_{L_0} - \gamma\alpha)\, exp\, (-\alpha^{-1} t) + T_L + \gamma\alpha \qquad (6.3)$$

T_0 is understood as the measured air temperature at the time t = 0. Equation (6.3) is not valid only for temperature measurements. It also applies for all parameters that show a gradient and are measured by inert instruments

For large values of t the first term on the right side if (6.3) vanishes. So (6.3)simplifies to (6.4) :

$$T - T_L = \gamma \cdot \alpha \qquad (6.4)$$

On the basis of equation (6.4) some important statements on the reliability of temperature measurements can be deduced:

1) The measured gradient γ corresponds to the real gradient for sections with constant α .

2) The measured temperature stays behind the true temperature by a constant amount for sections with $\gamma \cdot \alpha$ = const. The sign of the lag in temperature is controlled by the sign of the temperature gradient.

3) The sensor needs a time of α seconds to pass the temperature differences of $\gamma \cdot \alpha$. In other words: The sensor gives at the time $t + \alpha$ the true temperature at the time t.

4) The greater the climbing speed of the radiosonde the greater becomes the difference between true air temperature and measured temperature.

Point 4) represents one reason for the incapability to give general correction values for the radiosonde measurements. The climbing speed is not only controlled by the gas filling of the balloon but also by its shape. Expansion on the envelope as well as vertical and horizontal wind speed contribute to the deformation of the balloon. All these factors cannot be described exactly in their influence on the climbing speed since the meteorological conditions may change from one radiosounding to another.

6.3 The radiosoundings during Tellus JMC

Unfavorable weather conditions prevented scanner measurements by airplane until June, 20th. Such scanning flights were carried out on June, 20th, 21st and 22nd. Since the time when these flights took place did not correspond to the times of routine radiosonde measurements extra radiosonds had to be flown. The times at which such additional radiosoundings were performed were June, 20th 18 GMT, June, 21st 6 GMT and 16 GMT and June, 22nd 6 GMT. For the lack of staff measurements had to be omitted on June, 21st 16 GMT. All times refer to the start of the radiosonde. One radiosounding lasted approximately 1 to 1.5 hours. It must be mentioned that the radiosonde data from June, 22nd 6 GMT are not representative for the weather conditions under which the scanner flight of the past night had been taken place. The radiosounding in question was made during a thunderstorm in the early morning of June, 22nd.

The radiosonde date are drawn in form of a time section on thermodynamical diagram papers. For this purpose the "STÜWE"-diagram as used in the German Meteorological Service was taken. The vertical profiles of air temperature and relative humidity are inserted into seperate diagrams (cf. Fig. 6.2). The wind vectors are drawn together with the appropriate temperature profiles. Each diagram contains six radiosoundings.

6.4 Weather radar pictures

In addition to the radiosoundings photographs of the weather radar installed at the meteorological office were taken at about 12 GMT each day during the measuring campaign. The weather radar picture does not show the actual cloud situation since it can only detect droplets which exceed a certain minimum size. In the case mentioned the

droplets must have a radius of at least 10^{-2} cm to be recorded by the weather radar. Therefore a shallow Sc-cover formed at the upper boundary of an inversion does not appear on the radar sreen. On days without detectable clouds no radar pictures were made. In order to improve the spatial resolution the radar range was limited to 100 km.

Fig. 6.3 shows the photographs taken from a WR (weather radar) 100-5 plan position indicator. The WR 100-5 is situated in Hanover-Langenhagen not far from the northern runway of the airport near the radiosonde station (cf. Fig. 4.1). The pictures should give a qualitative overview of the cloud situation of the environment of Ruthe. From June, 17th to 21st the WR 100-5 has been switched off because of the weather situation.

Literature of sect. 6:

Deutscher Wetterdienst	: Europäischer Wetterbericht, Aerologische Wettermeldungen, Offenbach (Main), fortlaufend
Hesse, W.	: Handbuch der Aerologie. Akad. Verlagsges. Leipzig, 381-458, Leipzig, 1961.
Hinzpeter, M.	: Eine neue Radiosonde. In: Ann. Meteorol. 7-9 , 393ff, 1951.
Möller, F. u. K. Bullrich	: Thermodynamische Grundlagen. In: Hesse,W. Handbuch der Aerologie. Leipzig, 1961.
Promet, meteorologische Fortbildung 3, 1973. Meßtechnik u. Automation.	Deutscher Wetterdienst, Offenbach (Main), 1973.

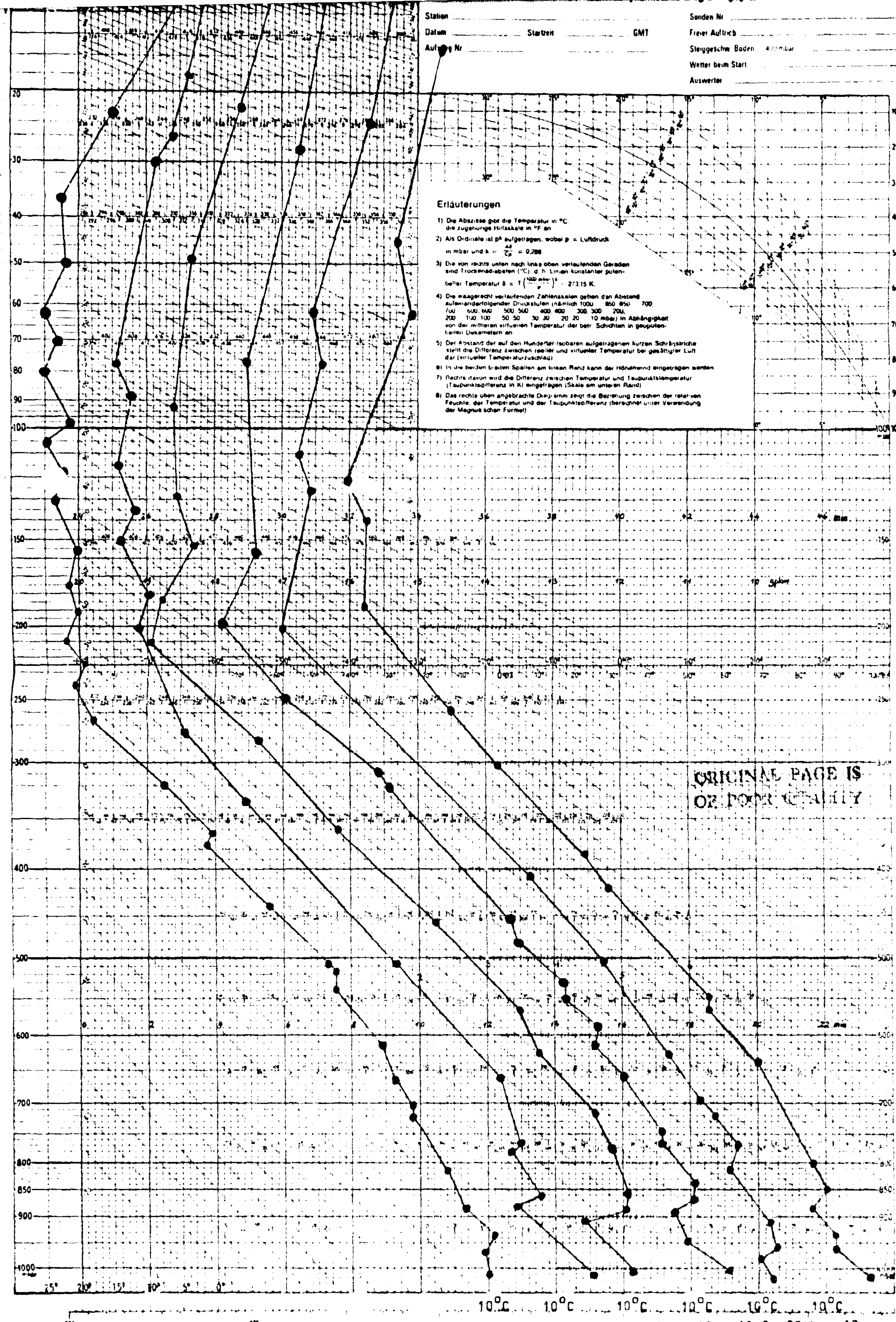
Table 6.1 Order of radar pictures taken at the weather bureau at Hanover-Langenhagen

Number	Day	Time in GMT	Elevation of antenna in deg.	Range in km
1	12.6.79	9.47	1.1	100
2	12.6.79	12.35	1.1	100
3	13.6.79	9.43	1.2	100
4	13.6.79	9.45	1.2	200
5	13.6.79	13.04	0.4	100
6	14.6.79	9.37	1.1	100
7	14.6.79	13.00	0.5	100
8	15.6.79	9.40	0.4	100
9	15.6.79	12.27	0.3	100
10	16.6.79	9.43	0.2	100
11	16.6.79	12.17	0.5	100
12	22.6.79	10.21	0.3	100

Photograph 1 shows not movable targets.

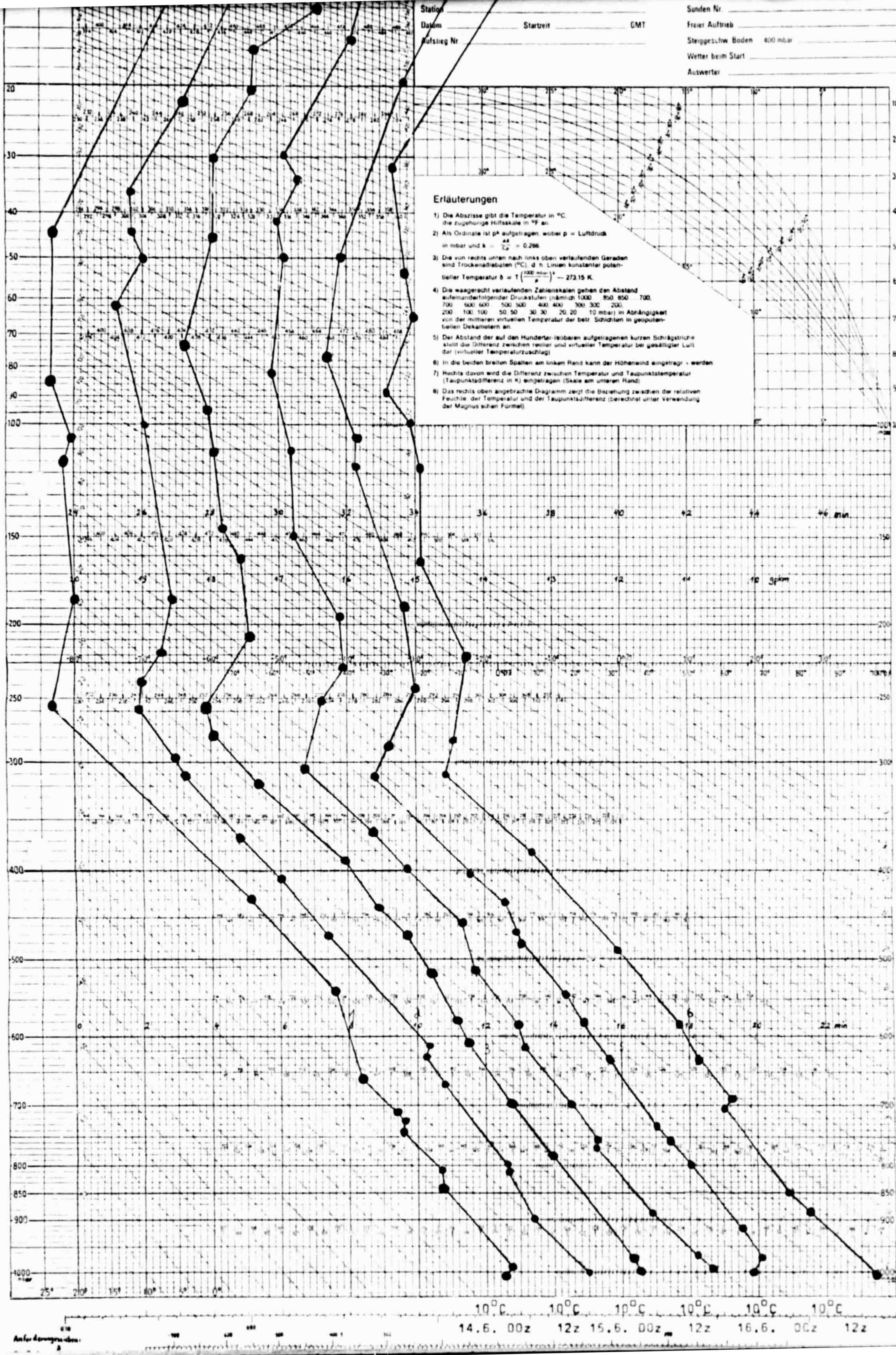
List of illustration of sect. 6:

List of tables of sect. 6:

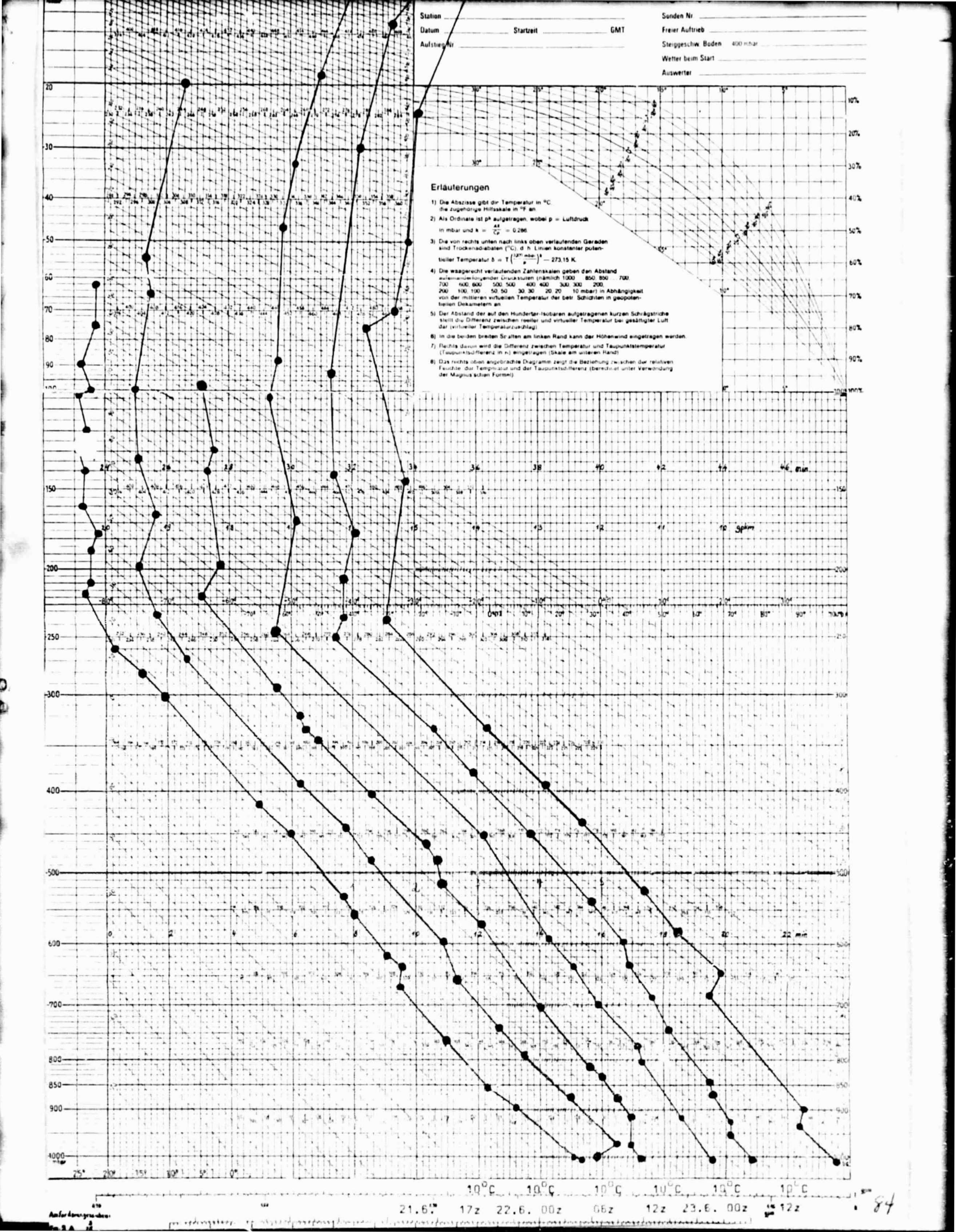


10°C 10°C 10°C 10°C 10°C 10°C

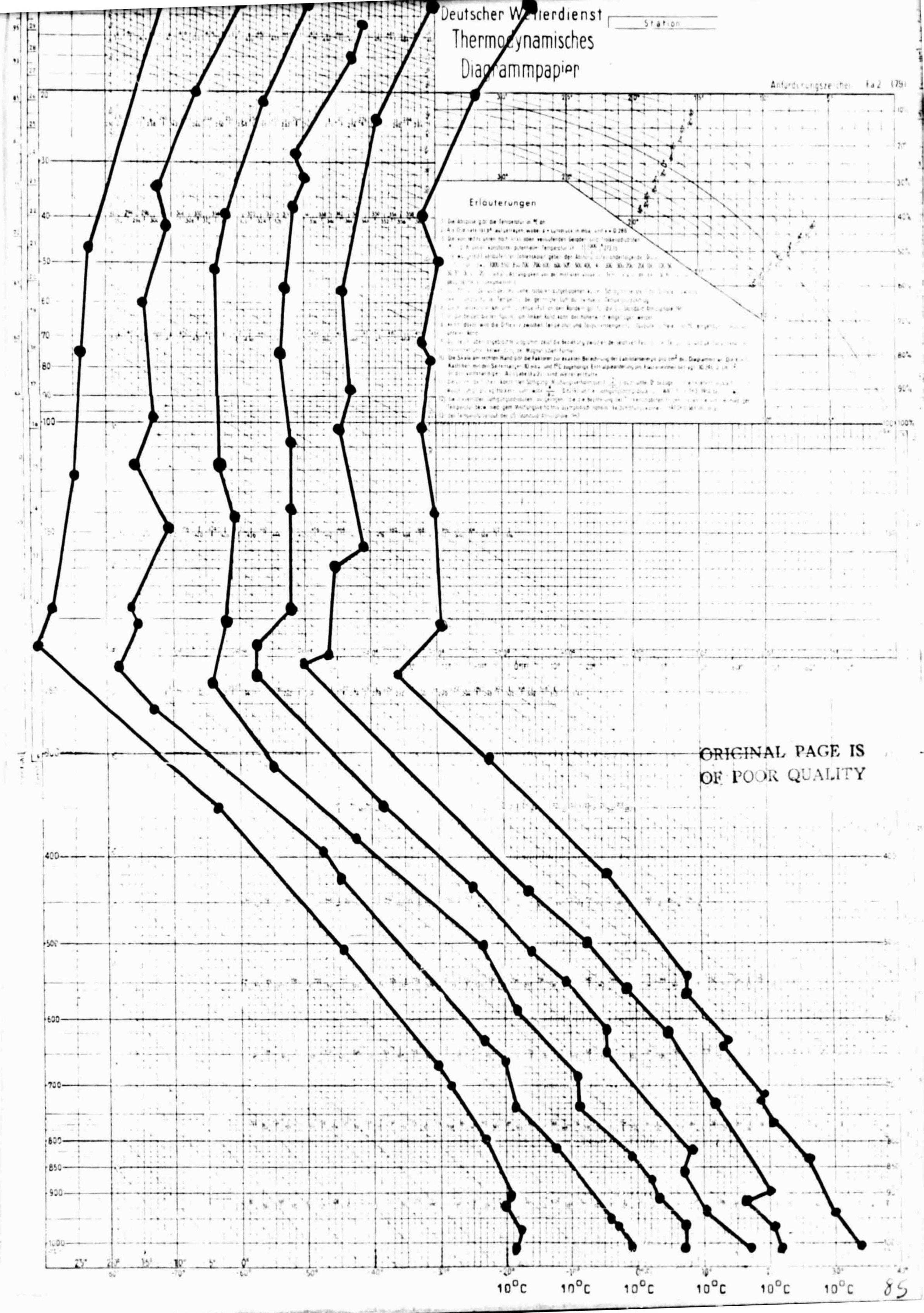
17.6. 00z 12z 18.6. 00z 12z 19.6. 00z 12z


Station
Datum
Startzeit
GMT
Aufstieg Nr.
Sonden Nr.
Freier Auftrieb
Steiggeschw. Boden
400 mbar
Wetter beim Start
Auswerter
Erläuterungen
1) Die Abszisse gibt die Temperatur in °C, die zugehörige Hilfsskale in °F an.
2) Als Ordinate ist p^k aufgetragen, wobei p = Luftdruck in mbar und k = AR/cp = 0.286
3) Die von rechts unten nach links oben verlaufenden Geraden sind Trockenadiabaten (°C), d. h. Linien konstanter potentieller Temperatur ϑ = T (1000 mbar/p)^k − 273.15 K.
4) Die waagerecht verlaufenden Zahlenskalen geben den Abstand aufeinanderfolgender Druckstufen (nämlich 1000 ... 850, 850 ... 700, 700 ... 600, 600 ... 500, 500 ... 400, 400 ... 300, 300 ... 200, 200 ... 100, 100 ... 50, 50 ... 30, 30 ... 20, 20 ... 10 mbar) in Abhängigkeit von der mittleren virtuellen Temperatur der betr. Schichten in geopotentiellen Dekametern an.
5) Der Abstand der auf den Hunderter-Isobaren aufgetragenen kurzen Schrägstriche stellt die Differenz zwischen reeller und virtueller Temperatur bei gesättigter Luft dar (virtueller Temperaturzuschlag).
6) In die beiden breiten Spalten am linken Rand kann der Höhenwind eingetragen werden.
7) Rechts davon wird die Differenz zwischen Temperatur und Taupunktstemperatur (Taupunktsdifferenz in K) eingetragen (Skale am unteren Rand).
8) Das rechts oben angebrachte Diagramm zeigt die Beziehung zwischen der relativen Feuchte, der Temperatur und der Taupunktsdifferenz (berechnet unter Verwendung der Magnus'schen Formel).
10°C
10°C
10°C
10°C
10°C
10°C
14.6. 00z
12z
15.6. 00z
12z
16.6. 00z
12z

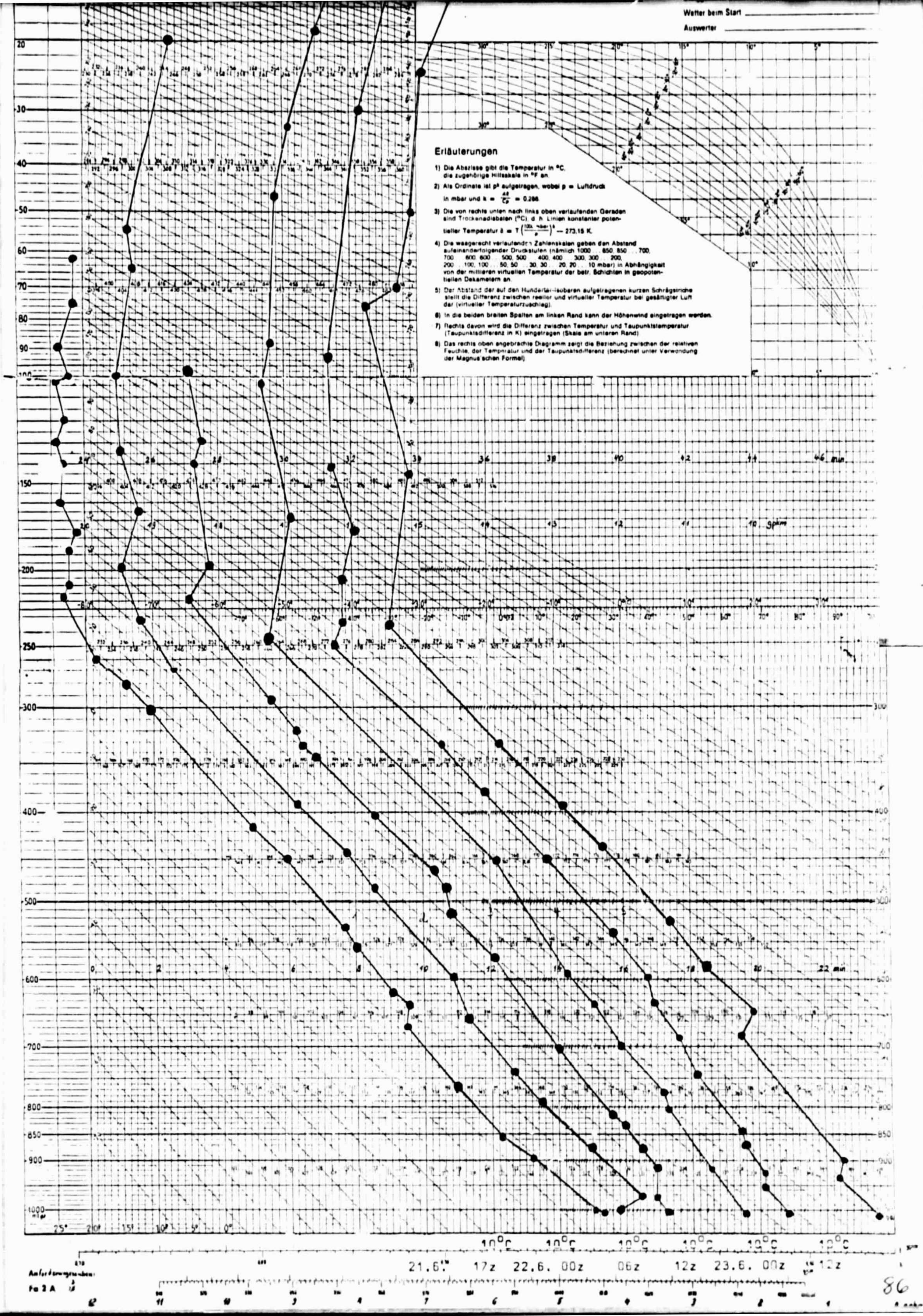
83



Station
Datum
Startzeit
GMT
Aufstieg Nr
Sonden Nr
Freier Auftrieb
Steiggeschw. Boden
400 mbar
Wetter beim Start
Auswerter
Erläuterungen
1) Die Abszisse gibt dir Temperatur in °C, die zugehörige Hilfsskale in °F an.
2) Als Ordinate ist p^k aufgetragen, wobei p = Luftdruck in mbar und $k = \frac{AR}{c_p} = 0{,}286$.
3) Die von rechts unten nach links oben verlaufenden Geraden sind Trockenadiabaten (°C), d. h. Linien konstanter potentieller Temperatur $\vartheta = T\left(\frac{1000\ \text{mbar}}{p}\right)^k - 273{,}15$ K.
4) Die waagerecht verlaufenden Zahlenskalen geben den Abstand aufeinanderfolgender Druckstufen (nämlich 1000 ... 850, 850 ... 700, 700 ... 600, 600 ... 500, 500 ... 400, 400 ... 300, 300 ... 200, 200 ... 100, 100 ... 50, 50 ... 30, 30 ... 20, 20 ... 10 mbar) in Abhängigkeit von der mittleren virtuellen Temperatur der betr. Schichten in geopotentiellen Dekametern an.
5) Der Abstand der auf den Hunderter-Isobaren aufgetragenen kurzen Schrägstriche stellt die Differenz zwischen reeller und virtueller Temperatur bei gesättigter Luft dar (virtueller Temperaturzuschlag).
6) In die beiden breiten Spalten am linken Rand kann der Höhenwind eingetragen werden.
7) Rechts davon wird die Differenz zwischen Temperatur und Taupunktstemperatur (Taupunktsdifferenz in K) eingetragen (Skale am unteren Rand).
8) Das rechts oben angebrachte Diagramm zeigt die Beziehung zwischen der relativen Feuchte, der Temperatur und der Taupunktsdifferenz (berechnet unter Verwendung der Magnus'schen Formel).
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
20
30
40
50
60
70
80
90
150
200
250
300
400
500
600
700
800
850
900
1000 mbar
10°C
10°C
10°C
10°C
10°C
10°C
21.6. 17z
22.6. 00z
06z
12z
23.6. 00z
12z
84


Deutscher Wetterdienst
Station
Thermodynamisches
Diagrammpapier
Erläuterungen
10°C
10°C
10°C
10°C
10°C
10°C

Wetter beim Start
Auswerter



Erläuterungen

1) Die Abszisse gibt die Temperatur in °C, die zugehörige Hilfsskale in °F an.

2) Als Ordinate ist p^k aufgetragen, wobei p = Luftdruck in mbar und $k = \frac{R}{c_p} = 0.286$.

3) Die von rechts unten nach links oben verlaufenden Geraden sind Trockenadiabaten (°C), d. h. Linien konstanter potentieller Temperatur $\vartheta = T\left(\frac{1000\ \text{mbar}}{p}\right)^k - 273{,}15$ K.

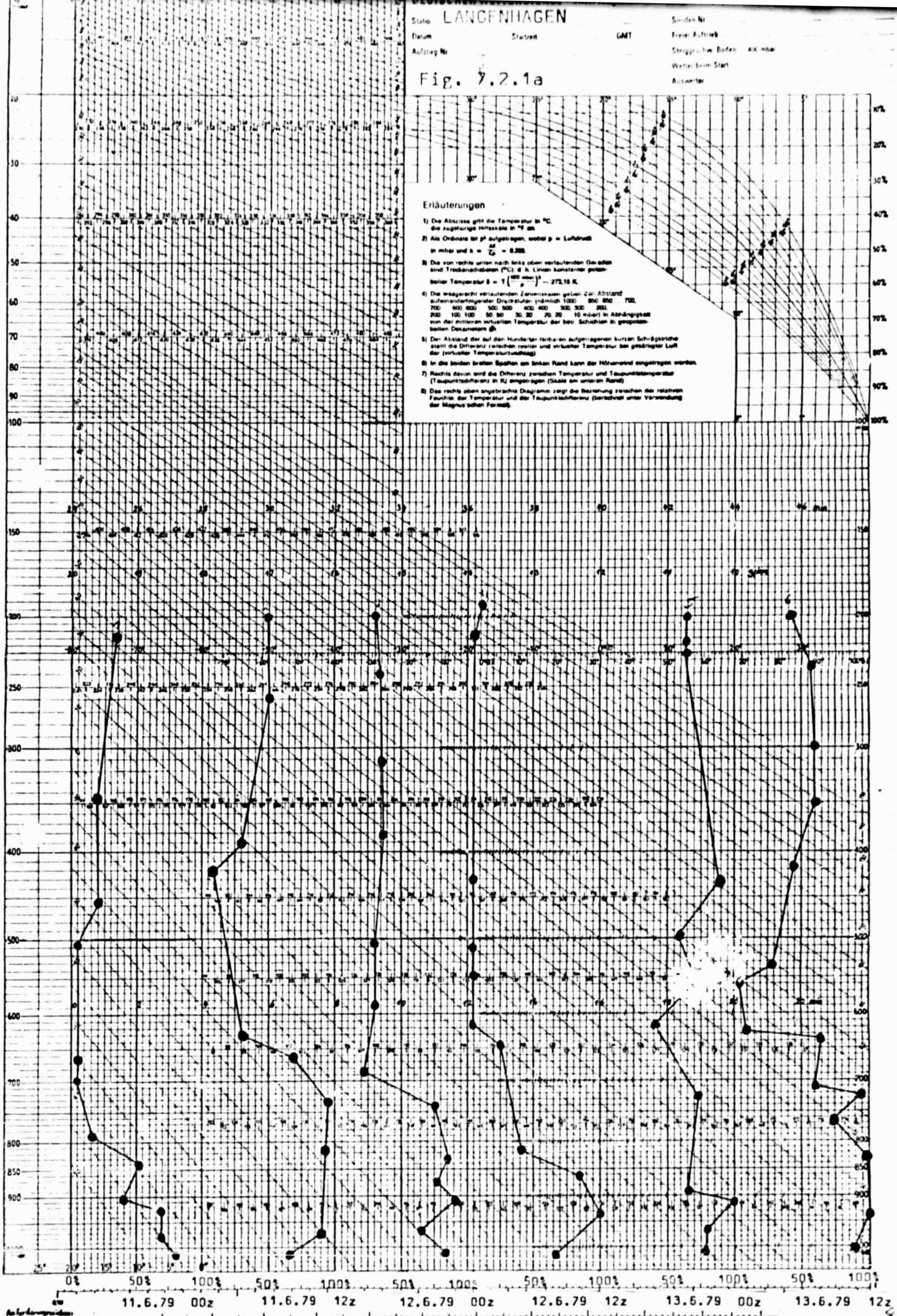
4) Die waagerecht verlaufenden Zahlenskalen geben den Abstand aufeinanderfolgender Druckstufen (nämlich 1000 ... 850, 850 ... 700, 700 ... 600, 600 ... 500, 500 ... 400, 400 ... 300, 300 ... 200, 200 ... 100, 100 ... 50, 50 ... 30, 30 ... 20, 20 ... 10 mbar) in Abhängigkeit von der mittleren virtuellen Temperatur der betr. Schichten in geopotentiellen Dekametern an.

5) Der Abstand der auf den Hunderter-Isobaren aufgetragenen kurzen Schrägstriche stellt die Differenz zwischen reeller und virtueller Temperatur bei gesättigter Luft dar (virtueller Temperaturzuschlag).

6) In die beiden breiten Spalten am linken Rand kann der Höhenwind eingetragen werden.

7) Rechts davon wird die Differenz zwischen Temperatur und Taupunktstemperatur (Taupunktsdifferenz in K) eingetragen (Skale am unteren Rand).

8) Das rechts oben angebrachte Diagramm zeigt die Beziehung zwischen der relativen Feuchte, der Temperatur und der Taupunktsdifferenz (berechnet unter Verwendung der Magnus'schen Formel).


Station LANGENHAGEN
Datum
Startzeit
GMT
Aufstieg Nr
Sonden Nr
Freier Auftrieb
Steiggeschw. Boden
Wetter beim Start
Auswerter
Fig. 7.2.1a
Erläuterungen
11.6.79 00z
11.6.79 12z
12.6.79 00z
12.6.79 12z
13.6.79 00z
13.6.79 12z

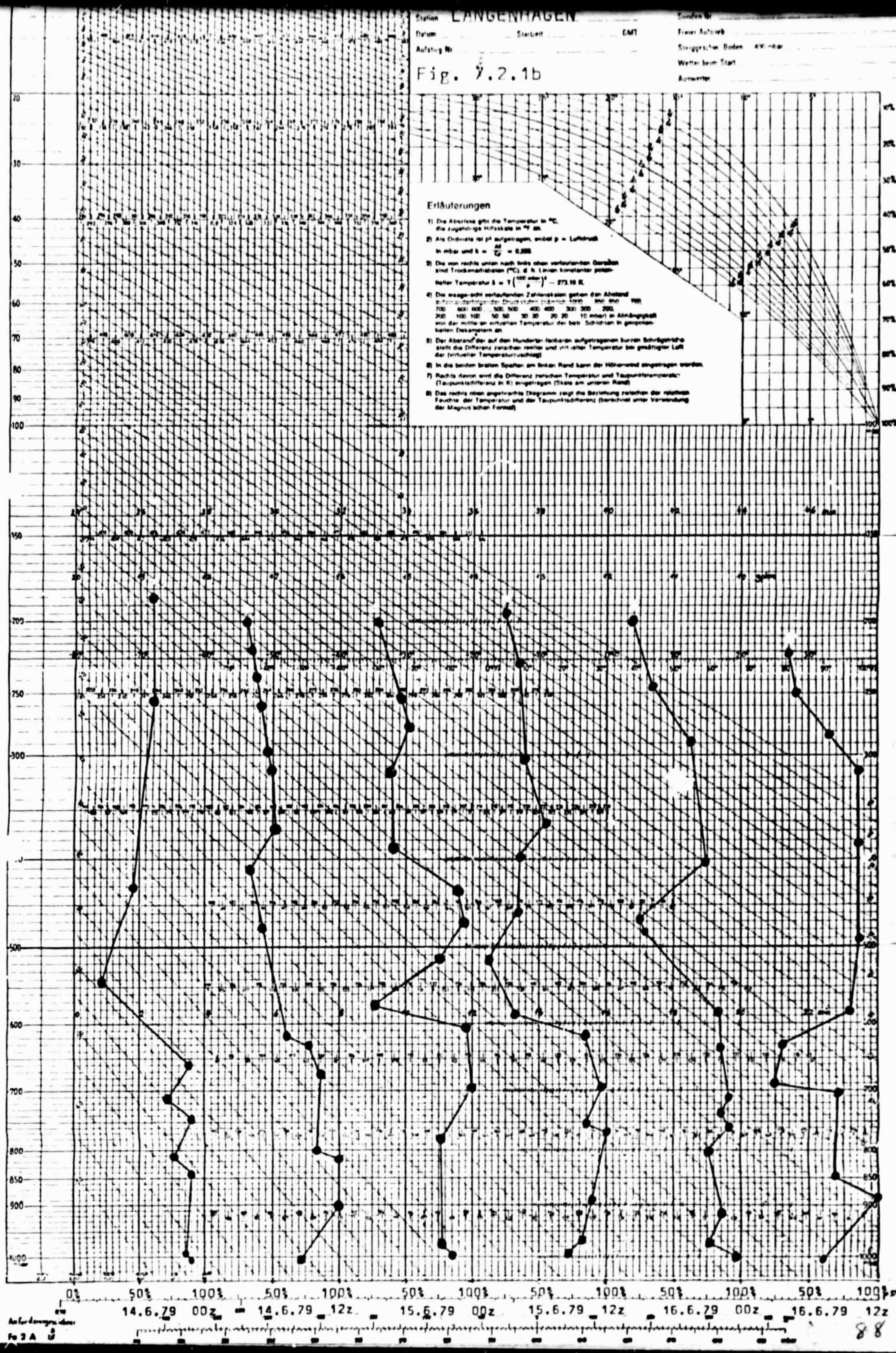
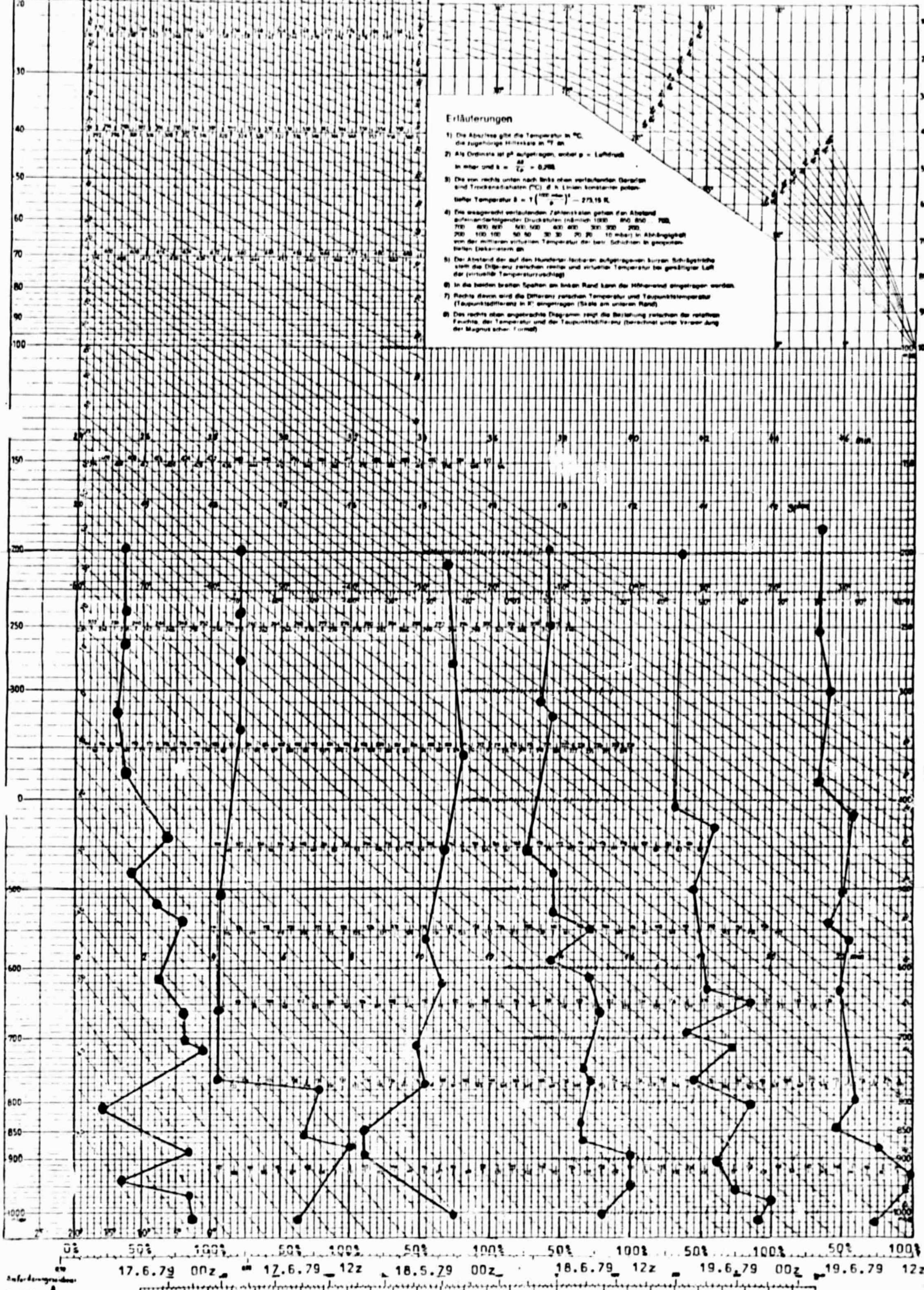

Station LANGENHAGEN
Datum
Startzeit
GMT
Aufstieg Nr.
Sonden Nr.
Freier Auftrieb
Steiggeschw. Boden
Wetter beim Start
Auswerter
Erläuterungen
1) Die Abszisse gibt die Temperatur in °C, die zugehörige Hilfsskala in °F an.
2) Als Ordinate ist p^k aufgetragen, wobei p = Luftdruck in mbar und k = 0,288
3) Die von rechts unten nach links oben verlaufenden Geraden sind Trockenadiabaten (°C), d. h. Linien konstanter potentieller Temperatur
4) Die waagerecht verlaufenden Zahlenskalen geben den Abstand aufeinanderfolgender Druckstufen
5) Der Abstand der auf den Hunderter-Isobaren aufgetragenen kurzen Schrägstriche stellt die Differenz zwischen reeller und virtueller Temperatur bei gesättigter Luft dar (virtueller Temperaturzuschlag)
6) In die beiden breiten Spalten am linken Rand kann der Höhenwind eingetragen werden.
7) Rechts davon wird die Differenz zwischen Temperatur und Taupunktstemperatur (Taupunktsdifferenz in K) eingetragen (Skala am unteren Rand)
8) Das rechts oben angebrachte Diagramm zeigt die Beziehung zwischen der relativen Feuchte, der Temperatur und der Taupunktsdifferenz (berechnet unter Verwendung der Magnus'schen Formel)
0% 50% 100% 50% 100% 50% 100% 50% 100% 50% 100% 50% 100%
14.6.79 00z
14.6.79 12z
15.6.79 00z
15.6.79 12z
16.6.79 00z
16.6.79 12z

Fig. 7.2.1b

Fig. 7.2.1c



Erläuterungen
17.6.79 00z
17.6.79 12z
18.5.79 00z
18.6.79 12z
19.6.79 00z
19.6.79 12z
0%
50%
100%

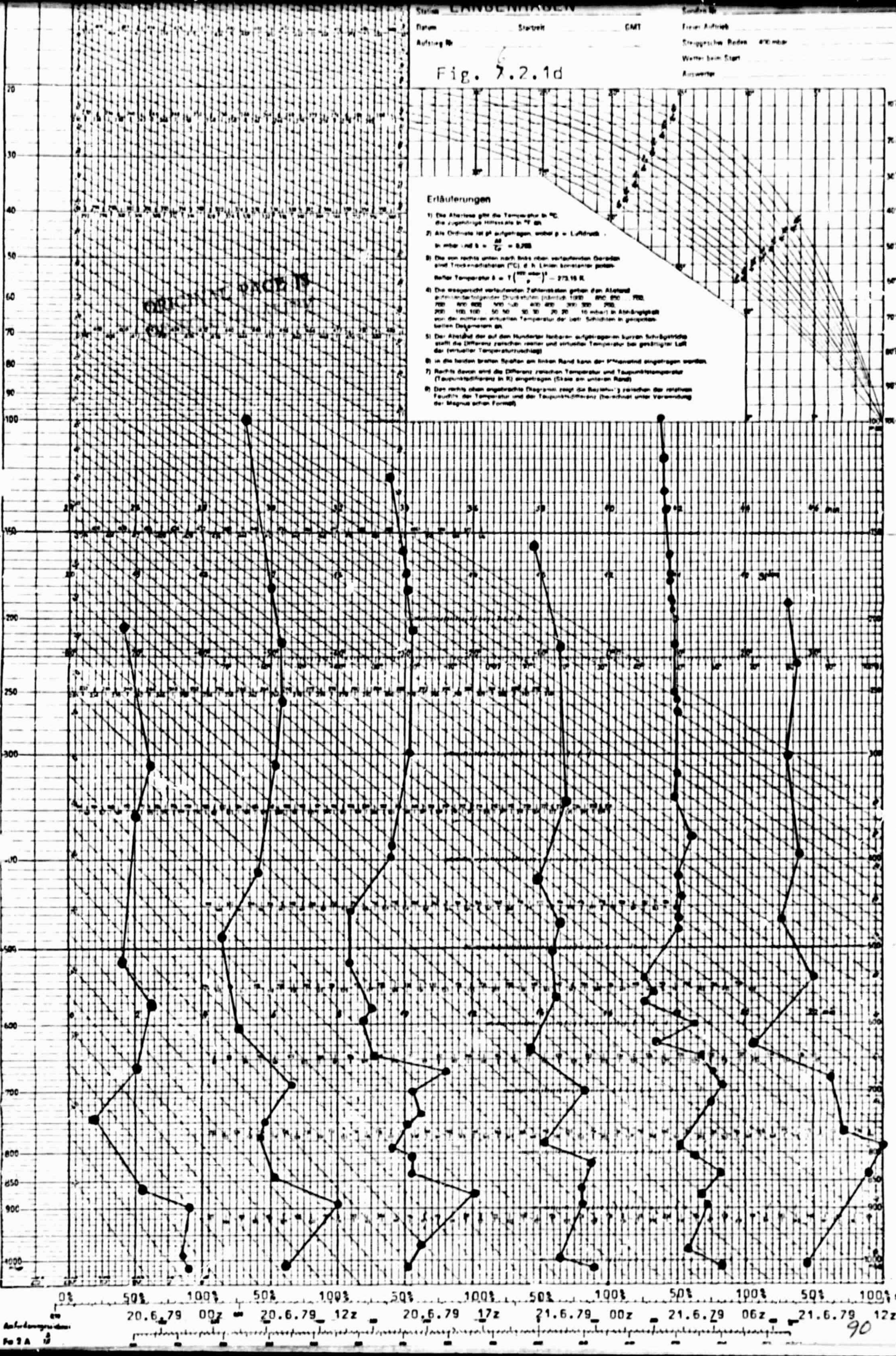
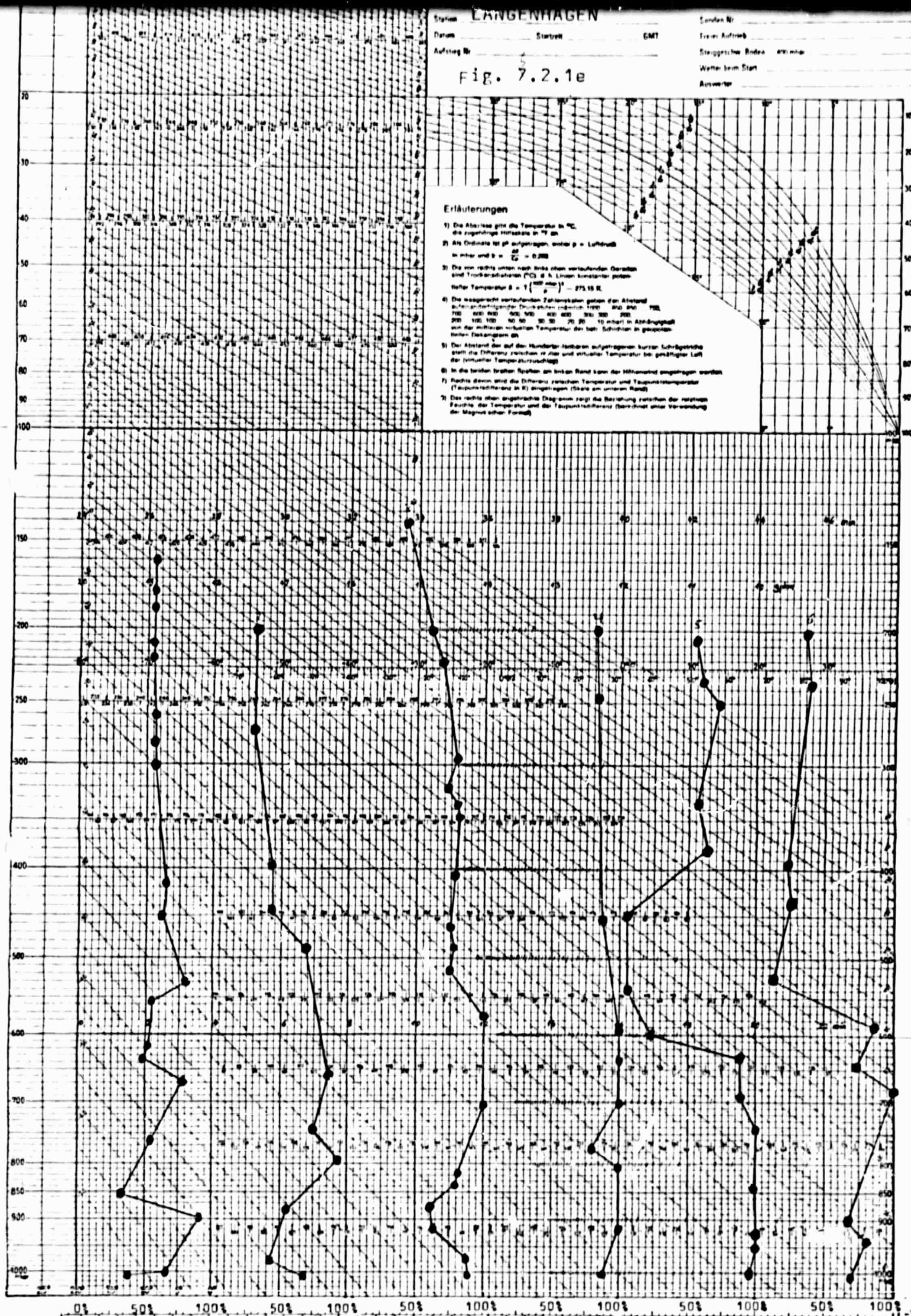

Station
Datum
Startzeit
GMT
Aufstieg Nr
Erläuterungen
0%
50%
100%
20.6.79 00z
20.6.79 12z
20.6.79 17z
21.6.79 00z
21.6.79 06z
21.6.79 12z

Fig. 7.2.1d



21.6.79 17z 22.6.79 00z 22.6.79 06z 22.6.79 12z 23.6.79 00z 23.6.79 12z

7. The Plant Root Distribution

U. Köpke and W. Böhm

Institut für Pflanzenbau und Pflanzenzüchtung der Universität Göttingen, Von Siebold Str. 4, 3400 Göttingen

Introduction and objectives

One of the main objectives of the Joint Measuring Campaign in Ruthe was to describe the exchange of water and heat between crop canopies and the atmosphere. In order to describe the interactions between meteorological influences, soil-water conditions and plant growth, it is necessary to have detailed information about the root distribution. A number of methods to study the plant root distribution has been developed and could have been used (see Böhm, 1979). For the particular situation in Ruthe it was decided to work with an in situ method, usually denoted as trench profile method. In a recently comparison of methods for measuring root growth (Köpke, 1979) it was demonstrated that the trench profile method has some remarkable attributes. The method has a favorable ratio of expended labour to information that is gained. Determination of root length in situ is possible. Precision and accuracy are high. The present study describes this method briefly and gives a general survey about the root distribution of the crops at Ruthe. More detailed data may be obtained from the authors or from the Joint Research Centre at Ispra.

Methods and materials

The investigations were conducted on sugar beets (Field Nr. 2), winter barley (Field Nr. 3), winter wheat (Field Nr. 4), and on spring barley (Field Nr. 6), on 15 June 1979. Within each field a 150-cm long trench, 150 cm wide and deep was dug by hand transversely to the plant rows. The profile wall was prepared with a spade and smoothed with a special blade and a trowel with a serrated edge. The roots which protrude from the

working face of the profile wall were cut. Then a nearly 5-mm layer of soil was removed from the profile wall with the use of a fine beam of water (3 atm of pressure) and a small toothed scraper. After the roots had been exposed a frame (inner dimensions: 100 x 60 cm) with grids (5 x 5 xm) was fastened at the profile wall. The length of roots exposed was estimated by counting the number of 5 mm length units in each grid area. Roots of 10, 20 or 30 mm length were counted as 2, 4 or 6 length units. Number of root length units was directly mapped in a list resembling the frame on a smaller scale. Data can be given as root length densities (cm root/cm^3 soil) if it is postulated, that exact 5 mm soil were removed from the profile wall. For further details about the method see Böhm (1979).

Results and discussion

Estimated root length densities and relative root distribution are shown in Table 1. Highest root length densities were generally estimated in the upper soil layers. With increasing soil depth root length densities decreased steadily. In 30 cm depth a sudden decline of root length density marked the end of the plough horizon. It is obvious that the older plants, such as winter wheat and winter barley had higher root length densities and a deeper root penetration than the spring types. Hence, root distribution of the winter types was more uniform. Only in the upper layers of the plough horizon root length densities of spring barley were resembling the densities of winter types.

Comparing the data of winter wheat with data of other investigations accomplished with trench profile method, comparable soil conditions and the same stage of development (Böhm 1978, Köpke 1979), the root densities gained in Ruthe are lower. For sugar beets nearly the same root-length densities as Schmidt (personal communication) obtained, were estimated. For barley no comparable investigations are known.

C-2

The estimated root length obtained with the trench profile method cannot give the true root length density within the soil. In earlier studies Böhm (1976) and Köpke (1979) found that the estimated root length of cereals, obtained with the trench profile method, was about one half of that measured by root length of roots washed out of soil monoliths. A comparison between data obtained from the monolith method and from the trench profile method by Köpke (1979) for oats yielded a factor of 2.06. This factor seems to be proper for all grain crops. Consequently for making calculations,the original field data given in Table 1 should be multiplied by the factor 2.06.

Since the variation coefficient of root data is certainly high, the number of replications must be high too. Hence, for a coefficient of variation of 20 and a difference between treatments of d% = 20, Köpke (1979) calculated a number of 62 replications necessary to make differences significant with $\alpha = 0.05$ and $\beta = 0.10$. But in many cases differences between treatments are so small that only a few replications are necessary. When the trench profile method is applied, it is also possible to calculate the statistics in a hierarchical classification model. Then the 5 x 5 cm grids are considered as "sub-plots". It can be safely assumed that the trench profile method provides an adequate description of the real root distribution in the soil profile.

Figure 1 shows for illustrative purposes part of the data acquisition process in the field. The figure shows the root distribution of winter wheat (Field Nr. 4) with the number of root length units of each 5 x 5 cm grid transformed to points dotted in the corresponding position.

Acknowledgement

The authors gratefully acknowledge the assistance of Dr. R. Steinhardt and Mr. A.B. Dua.

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Böhm, W. 1976. In situ estimation of root length at natural soil profiles. J.Agric.Sci. 87, 365-368.

Böhm, W. 1978. Untersuchungen zur Wurzelentwicklung von Winterweizen. Z.Acker- u.Pflanzenbau 147, 264-269.

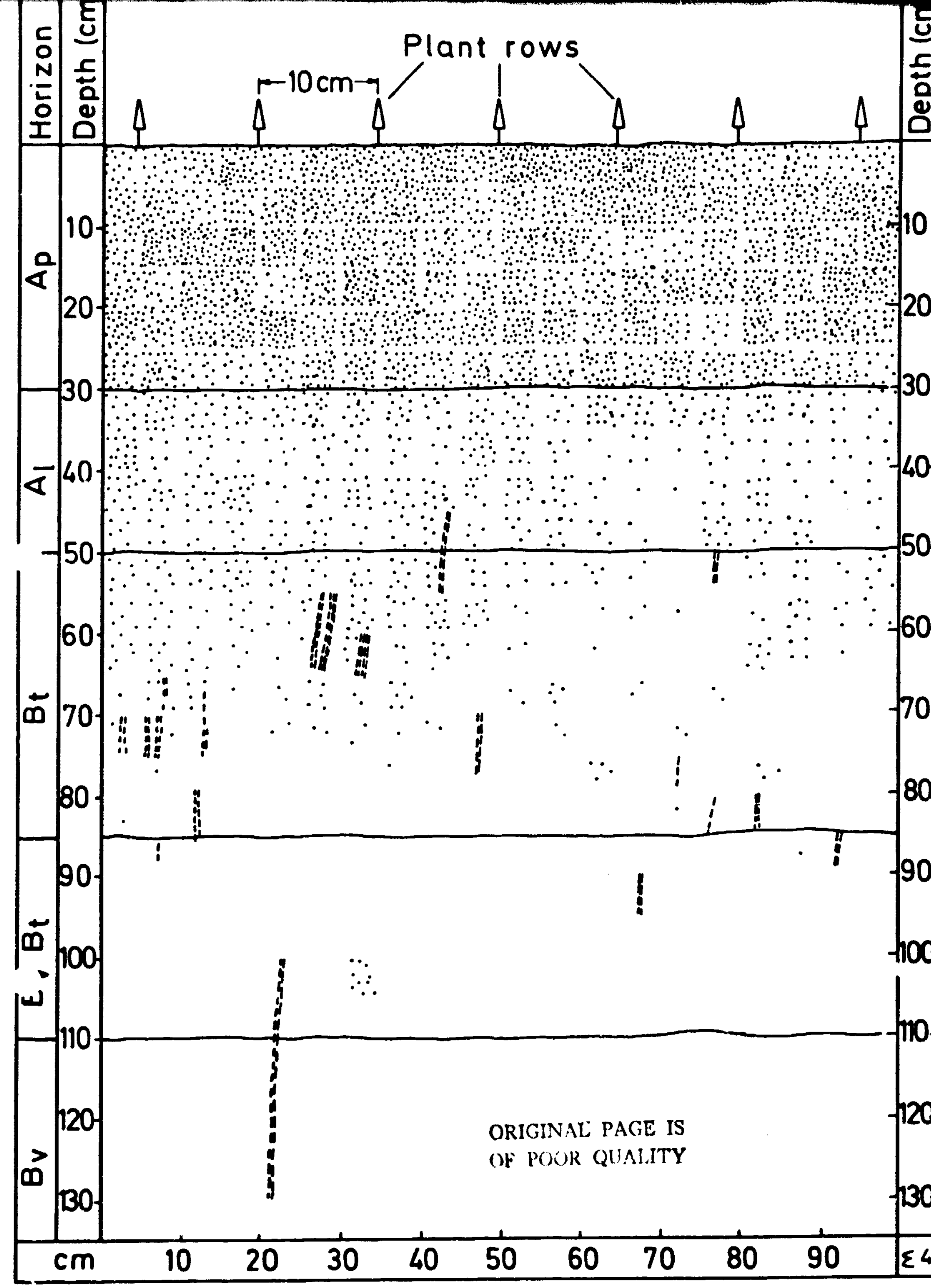
Böhm, W. 1979. Methods of Studying Root Systems. Ecological Studies Vol. 33, Springer-Verlag Heidelberg.

Köpke, U. 1979. Ein Vergleich von Feldmethoden zur Bestimmung des Wurzelwachstum landwirtschaftlicher Kulturpflanzen. Diss.Agric.Göttingen. (Ph.D.Thesis, Faculty of Agriculture, University of Göttingen).

LEGEND TO FIGURES AND TABLES OF CHAPTER 7

Table 1. The plant root distribution for Fields Nr. 2,3,4 and 6 on June 15.
[1] Average of 2 profiles that were investigated.
[2] Data of one profile.

Fig. 1. Root profile determinations on Field Nr. 4 (winter wheat) on June 15. One data point represents a unit of 5 mm root length. Roots growing in worm channels are indicated with dashed lines.



Number	%	Density cm
587	13	1,17
627	14	1,25
591	13	1,18
527	12	1,05
529	12	1,06
414	9	0,83
216	5	0,43
121	3	0,24
143	3	0,29
108	2	0,22
116	3	0,23
109	2	0,22
86	2	0,17
41	1	0,08
57	1	0,11
15	<1	0,03
26	1	0,05
11	<1	0,02
8	<1	0,02
0	0	0
10	<1	0,02
10	<1	0,02
10	<1	0,02
10	<1	0,02
10	<1	0,02
10	<1	0,02
Σ 4392	100	

Root profile of winter wheat (site nr. 4) at Ruthe on June 15 1979.
Fig.7.1

Onepoint = 5mm estimated root length at the profile wall. Roots growing in earth worm channels are marked with broken lines

Depth (cm)	Winter wheat[1]			Winter barley[2]			Spring barley[2]			Sugar beet[1]			Depth (cm)
	Number	%	Density cm/cm³	Number	%	Density cm/cm³	Number	%	Density cm/cm³	Number	%	Density cm/cm³	
	548	14	1.10	420	9	0.84	509	16	1.02	133	31	0.27	
10	561	15	1.12	526	12	1.05	508	16	1.02	57	13	0.11	10
	541	14	1.08	409	9	0.82	400	13	0.80	47	11	0.09	
20	449	12	0.90	403	9	0.81	310	10	0.62	89	21	0.18	20
	435	11	0.91	405	9	0.81	397	13	0.79	70	16	0.14	
30	387	10	0.77	353	8	0.71	252	8	0.50	23	5	0.05	30
	174	5	0.35	308	7	0.62	83	3	0.17	11	2	.02	
40	110	3	0.22	266	6	0.53	127	4	0.25	3	1	.01	40
	123	3	0.25	235	5	0.47	67	2	0.13				
50	94	3	0.19	168	4	0.34	38	1	.08				50
	90	2	0.18	170	4	0.34	62	2	0.12				
60	85	2	0.17	131	3	0.26	76	2	0.15				60
	61	2	0.12	108	2	0.22	74	2	0.15				
70	32	1	.06	111	2	0.22	47	1	.09				70
	36	1	.07	136	3	0.27	43	1	.09				
80	14	<1	.03	46	1	.09	29	1	.06				80
	18	<1	.04	43	1	.09	29	1	.06				
90	11	<1	.02	78	2	0.16	33	1	.07				90
	9	<1	.02	41	1	.08	29	1	.06				
100	9	<1	.02	31	1	.06	20	1	.04				100
	5	<1	.01	44	1	.09	8	<1	.02				
110	5	<1	.01	23	<1	.05	0		0.00				110
	5	<1	.01	20	<1	.04	2	<1	0.00				
120	5	<1	.01	18	<1	.04	2	<1	0.00				120
	5	<1	.01	20	<1	.04							
130	5	<1	.01										130
Σ	3817	100		4713	100		3145	100		433	100		

1) Average of 2 profiles that were investigated

2) Data of one profile

Root distribution patterns on fields 2,3,4 and 6 on June 1

Table 7.1

8. Crop Reflectivity and Emissivity

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Objectives

1. To establish the average spectral reflectance of each of the four surfaces studied in each of the four Landsat MSS bands and the first Thematic Mapper band.
2. To calibrate the Portable Multiband Radiometer (PMR) used against the Exotech-100 used by the Ispra investigators.
3. To determine crop emissivity data on the test site.

A. REFLECTIVITY

Instrumentation

Figure 1 shows the radiometer used to collect the data; this is the MK IV version of a PMR developed in the Geography Department of Reading University. In use the sensor unit is mounted to look vertically downwards from a four metre high aluminium mast, and this configuration is shown in schematic form in Figure 2. Separate detector-filter combinations were used for each band sensed, the resulting bandpass characteristics being as follows:

Simulated band		Actual PMR 50% bandwidth (nm)
Thematic Mapper	Band 1	455 - 505
Landsat MSS	Band 4	500 - 585
Landsat MSS	Band 5	615 - 690
Landsat MSS	Band 6	705 - 780
Landsat MSS	Band 7	780 - 995

These bands are shown graphically in Figure 3.

The spectral reflectance of each surface in each of the bands was measured relative to a standard Kodak grey card, the characteristics of which relative to a pressed $BaSO_4$ standard had been determined in the laboratory previously using a

Beckman ACTA MK IV Spectrophotometer. A set of five readings were taken of both the grey card and the white panel used by the Ispra investigators and the results are presented in Figure 4. From these results, it can be seen that with the exception of MSS Band 6, the grey card has a band reflectance approximately 30% that of the white panel. The discrepancy for band 6 is probably due to the fact that the response of the PMR to increasing illumination in this band is non-linear due to the use of a photoconductive rather than photovoltaic detector. This effect will not alter the applicability of results from surfaces measured in this band, since in practice all measurements were <u>relative</u> to the grey standard card.

The area on the ground sensed by the PMR from a height of four metres was a circle one metre in diameter. A photographic record of the surfaces measured was obtained by mounting a 35 mm camera next to the sensor unit and placing a one metre quadrat on the ground below.

Discussion of Results

1. Spectral reflectance of the four surfaces

The percentage band reflectance relative to the grey card for all the surfaces is presented in tabular form in Figure 5 and graphically in Figure 6. The points to note will be discussed separately for each surface.

a) Bare Soil Site

The spectral reflectance of this surface was measured on two separate occasions, one on 5th June when the soil surface was dry and once on 22nd June when the soil surface was moist. Of these two states the former is more likely to be representative of the surface when the aircraft flew over on 21/22 June. Figure 7 shows the band reflectance for the bare soil site plotted for the two dates; it can be seen that rainfall between 5th and 22nd June had moistened the surface and depressed the overall level of reflectance throughout the visible and near infrared. The reflectance curve for 5th June, when the surface was dry, shows a marked peak in the orange-red part of the spectrum (MSS 5) as is to be

expected from the reddish colour of the loessial soil, rich in Fe_2O_3. With the increased moisture content represented by the measurements of 22nd June this peak has decreased and the reflectance curve is typical of that of a dark soil, showing a slight overall increase into the near infrared. The decline of the reflectance of the moist soil compared to the increase of reflectance of the dry soil in MSS band 7 is probably due to absorption around 980 nm by water molecules present in the soil surface.

b) Sugar Beet Site

Twelve sets of measurements were recorded from sites arranged in a grid fashion throughout the field, these measurements were performed on 8th June when the soil surface was moist. The average percentage cover of sugar beet was found to be 25 %. It can be seen from the results presented in Figure 6 that the band reflectance from the sugar beet field is very similar to that from the bare soil site on 22nd June. This suggests that the presence of the sugar beet plants was having little effect on the spectral reflectance in the visible and near infrared from this site, overall, the field was behaving as moist bare soil.

However, one important aspect of the measurements conducted in the sugar beet field was the assessment of the effect of a small area of slightly darker soil near the southern edge of this field. The majority of the field had a Munsell colour (moist) of 10YR 4/4, but near the southern boundary this declined to 10YR 3/3 (moist). Figure 8 tabulates the results from nine sites located in the 10YR 4/4 area against those from three sites located in the 10YR 3/3 area. It can be seen that in this latter area the reflectance from the field deviates considerably from that measured on the remainder, and this variation should be noted before analysis of the entire field as a homogeneous unit proceeds.

c) The Barley and Wheat Sites

In both these fields the canopy closure was almost complete, and so problems of background reflectance from the soil should be absent. It can be seen from Figure 6 that the band

reflectances for the two crops were very similar, although the wheat tended to reflect more strongly in band 7 than the barley. In practice, this difference is unlikely to be of much use in crop discrimination since the standard deviation of the band 7 reflectance for each crop was high (shown in Figure 5). In summary, for this area, at this time of the year, it is unlikely if data collected in either MSS bands 4 to 7 or Thematic Mapper band 1 could adequately discriminate wheat from barley.

2. Calibration of the PMR against the Exotech-100

This was accomplished by measuring the absolute spectral reflectance reflected from the ground at six stations spread throughout the bare soil site. The results are presented in Figure 9, which also gives the average calibration factors derived from these results. There was a certain variability in the ratio of $\frac{\text{PMR band reflectance}}{\text{Exotech band reflectance}}$ evident amongst the six sites, but this is to be expected for the following reasons:

a) The spectral bands sensed by the PMR and the Exotech, although nominally the same as the Landsat MSS, are in fact slightly different as shown in Figure 10. Of the two, the PMR has the better fit to the Landsat MSS as shown in Figure 3.

b) Variations are evident in the data set due to fluctuating incoming solar radiation. Normally this would be counter-acted by taking all readings relative to a reference card, but this was not done in this case.

c) The PMR and the Exotech used had different fields-of-view, being 30° in the case of the former and [illegible]0° in the case of the latter.

Conclusions

The spectral reflectance of the four surfaces investigated, bare soil, sugar beet, wheat and barley, was measured in several bands spread throughout the visible and near infrared. Important temporal variations in band reflectance from the bare

soil were noted and related to variations in surface moisture. The sugar beet field was noted to be variable in soil type; this was evident in the spectral reflectance of the surface since the percentage cover of sugar beet plants was insufficient to mask the background soil reflectance contribution. Discrimination of wheat from barley with these data is unlikely to be successful. Calibration of the PMR against the Ispra Exotech-100 has been attempted and awaits comparable data from the bare soil site taken with the Exotech-100 for testing.

B. EMISSIVITY

In order to adequately test the behaviour of the Tellus and Tergra models for bare earth and different crops situations, one of the basic requirements was to determine real surface temperature. At each of the JMC test sites, apparent surface temperature was measured with infrared radiometers operating generally within the water absorption "window" of 8 μm - 14 μm. To derive real surface temperature from apparent surface temperature, a correction must be applied which accounts for the emissivity of the surface and for the reflected radiation from the surroundings. The latter was determined at the bare earth site through the use of a reference panel of known temperature and emissivity. Emissivity values for bare earth, wheat, barley and sugar beet were determined by experiment following the procedure described by Fuchs and Tanner (1966).

Measurements were taken between 02.30 and 03.00 GMT on a cloud-free night when reflected radiation was zero. 'Black-body' temperature measurements of the various surfaces were achieved by covering them with a bottomless box of height $\sim$ 1.5 m and base $\sim$ 0.6 m square. The inside surface of the box was covered with aluminium coated 'mylar' film which is highly reflective to thermal radiation. Crop temperature inside the box was measured by allowing the sensor head of a Barnes PRT-5 radiometer with 20^{o} optic to view through a 0.03 m diameter hole in the top of the bos. Rapid and accurate location of the radiometer head over the hole was facilitated through the use of a machined face-plate.

Apparent surface temperature RB was measured by supporting the radiometer in a vertical position 1.5 m above ground level. The box was then quickly moved into position underneath the radiometer to enable the real black-body temperature σT^4 to be determined. As the latter must be measured within about 10 seconds of positioning the box above the crop, voltage output from the radiometer was recorded on a fast-moving paper chart. From these data the emissivity of each surface, , was determined by

$$\varepsilon = \frac{Rb}{\sigma T^4}$$

Table 1 summarises the results, from which it can be seen that mean emissivity values range from 0.994, for the bare earth surface, to 0.999 for the barley and wheat crops. These values are considerably higher than would be expected for such surfaces and initial tests suggest that the problem may stem from the use of the 'mylar' based aluminium film as a thermal reflective lining to the inner surface of the 'black-body' box. Both mylar and ordinary aluminium foil were used as sky temperature reference panels for the UK Tellus overflight in September 1979. Whilst the aluminium foil provided a good measure of sky temperature, the mylar was recorded as a much higher signal around shade air temperature. This can be attributed to the fact that the aluminium coating is applied to only one surface of the mylar and unless that surface faces the radiometer, the apparent temperature of the thin mylar base is recorded instead of a reflected temperature. Although the mylar film is ideal for many field applications because of its resilience, care should be taken in its application. From the data collected, it should however be possible to derive a value of emissivity for the bare earth by comparison with previously measured values of barley and wheat emissivities.

Reference

Fuchs, M. and C.B. Tanner, Infrared thermometry of vegetation, Agronomy Journal, Vol.58, pp 597-601, 1966.

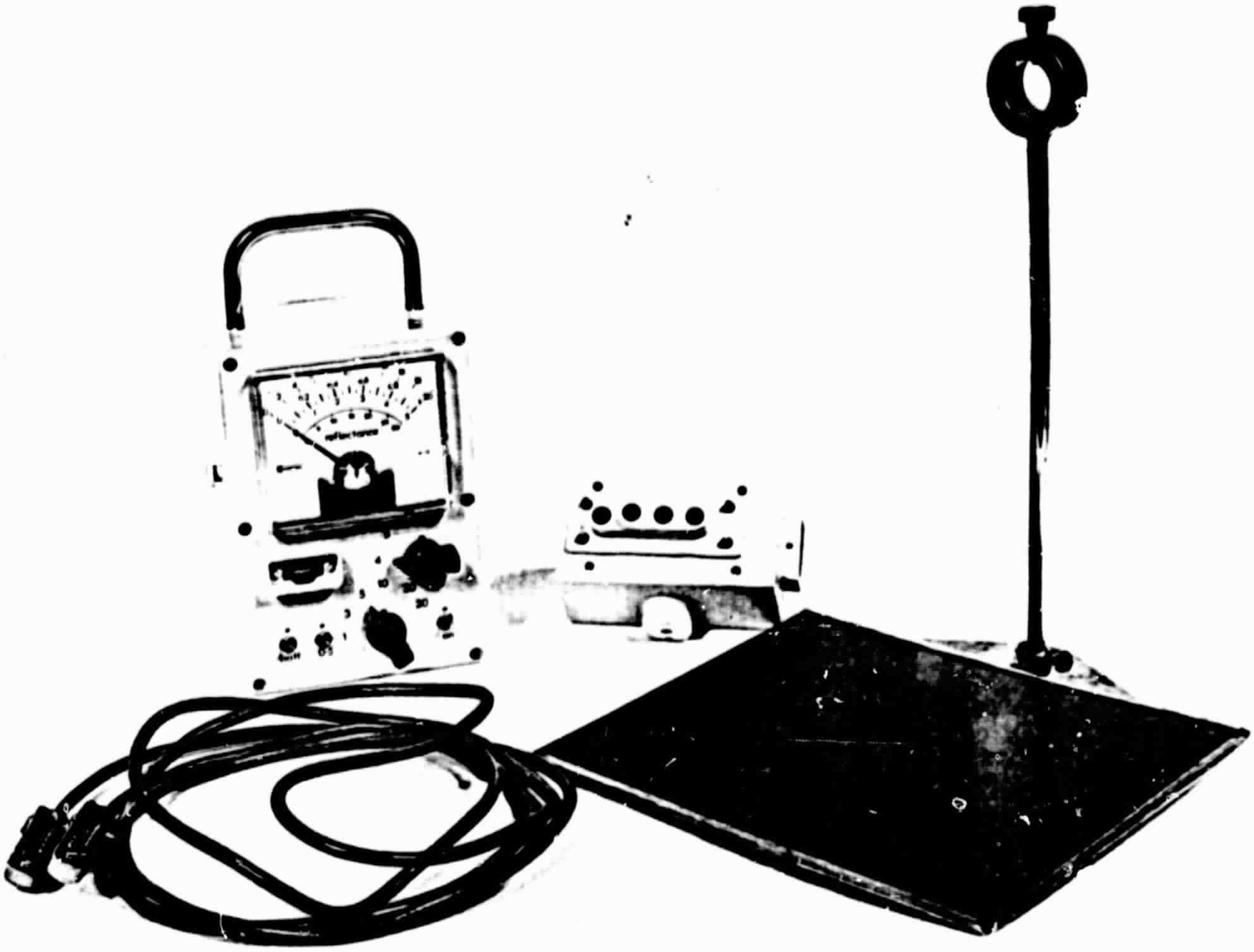


Figure 1.

Figure 2.

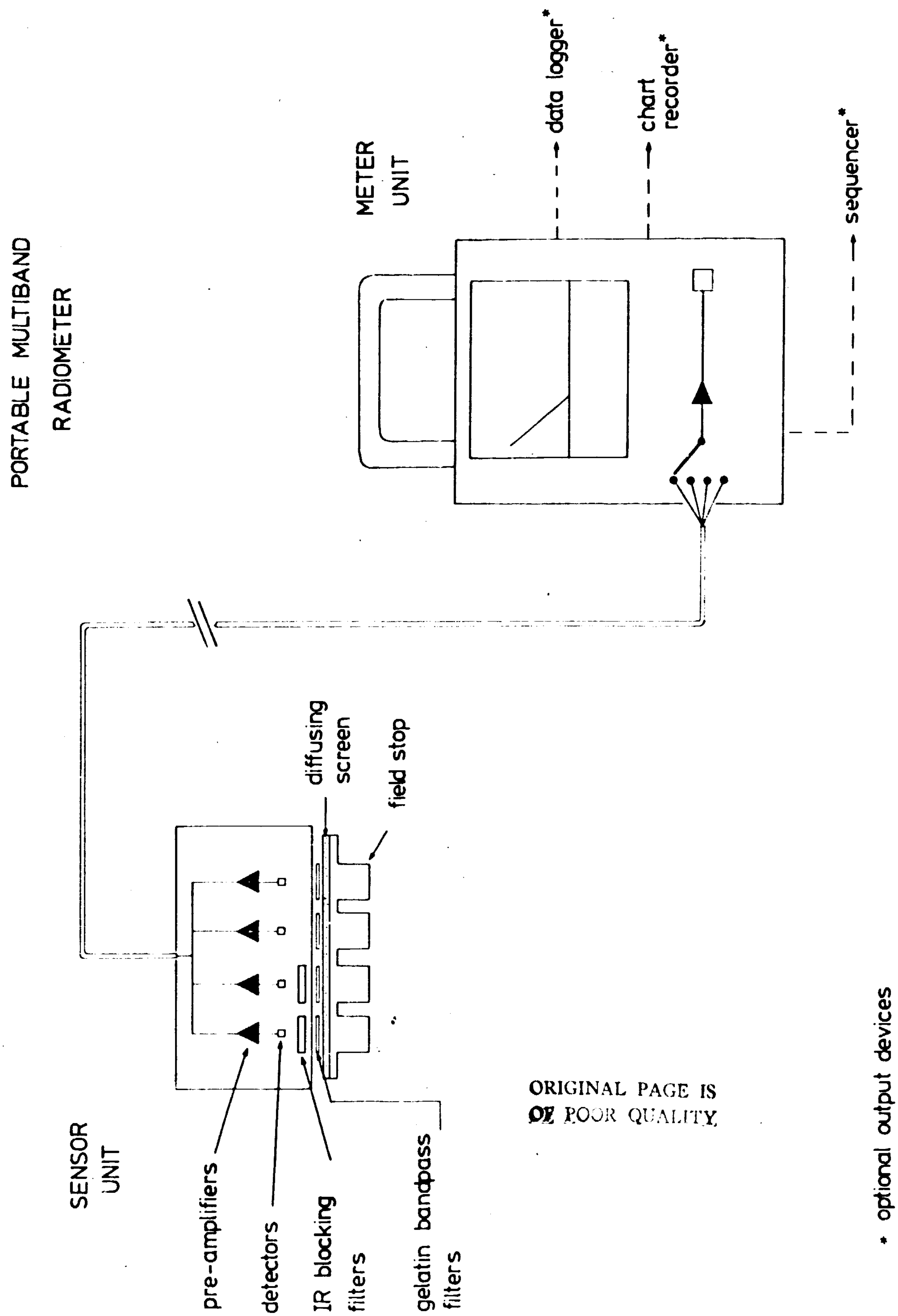
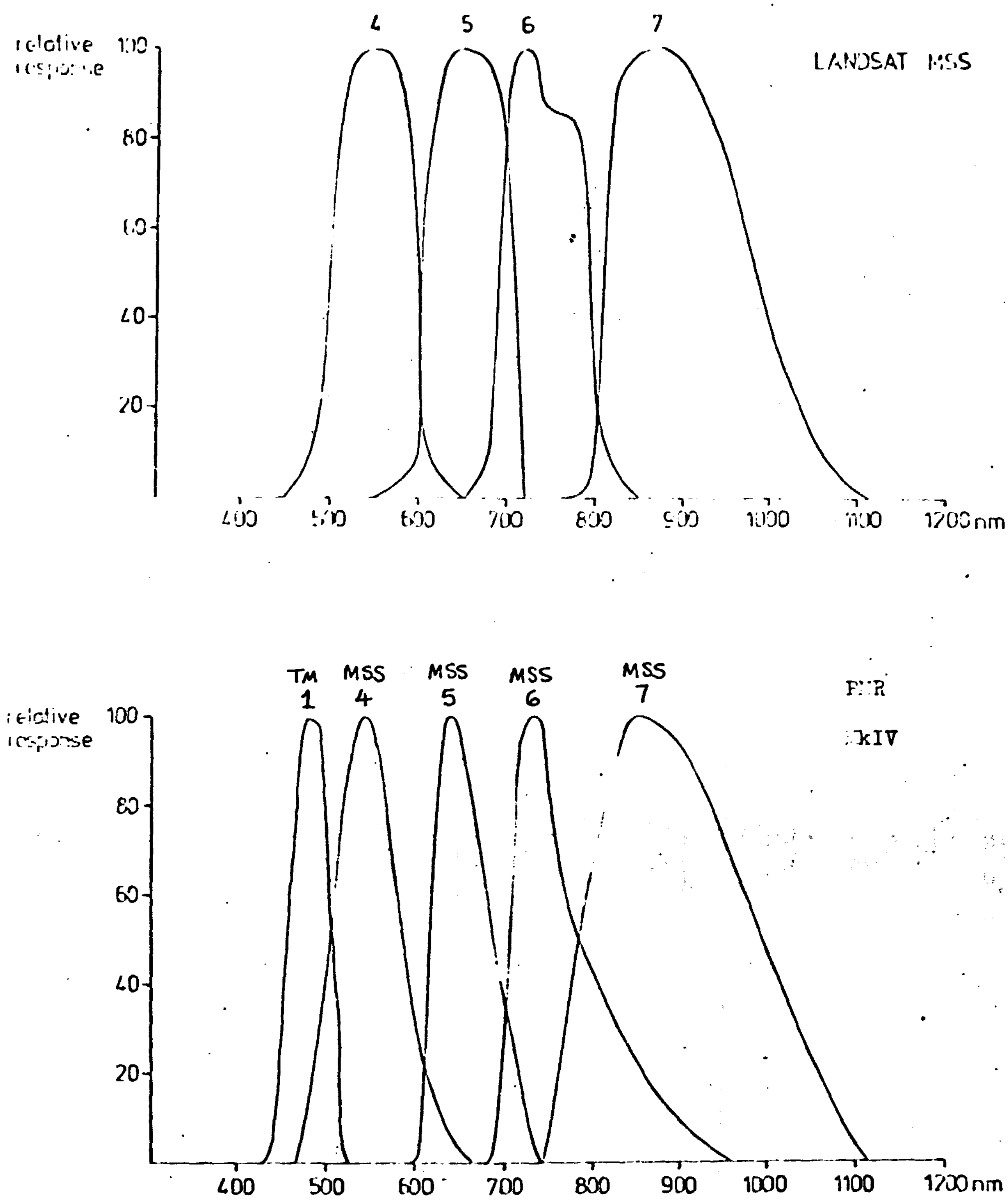

PORTABLE MULTIBAND
RADIOMETER
METER
UNIT
data logger*
chart
recorder*
sequencer*
SENSOR
UNIT
pre-amplifiers
detectors
IR blocking
filters
gelatin bandpass
filters
diffusing
screen
field stop
* optional output devices

Figure 3. [illegible] response of the [illegible] relative to the Landsat [illegible].



Each band individually normalized in both cases

Landsat MSS response generalized from the six sensor responses per band

Figure 4. Calibration of grey card against white panel

	Calib. 1	Calib. 2	Calib. 3	Calib. 4	Calib. 5	$\bar{x}$ / σ
TM 1	28	28	27	29	–	28 / 0.82
MSS 4	28	33	32	27	29	30 / 2.59
MSS 5	24	32	23	29	32	28 / 4.30
MSS 6	51	53	53	50	53	52 / 1.41
MSS 7	36	36	31	35	35	35 / 2.07

$\bar{x}$ (ignoring Band 6 data) = 30.25%

$$\bar{x} = \frac{\text{grey card band reflectance}}{\text{white panel band reflectance}}$$

Figure 5. % band reflectance for the 4 surfaces.

		TM 1	MSS4	MSS5	MSS6	MSS7	NUMBER OF STATIONS	
BARE SOIL 5/6	$\bar{x}$	99.8	118.4	155.1	128.1	165.0	4	TM
	σ	4.84	7.20	7.47	16.50	3.17	4	MSS
BARE SOIL 22/6	$\bar{x}$	N.A.	39.6	57.8	89.1	79.8	0	TM
	σ	N.A.	8.90	6.85	12.81	9.13	6	MSS
BARLEY	$\bar{x}$	32.7	31.5	33.0	121.7	178.9	4	TM
	σ	6.35	1.60	0.80	3.59	6.19	9	MSS
WHEAT	$\bar{x}$	28.6	27.4	35.9	120.7	202.6	5	TM
	σ	1.13	1.47	2.04	5.87	13.56	12	MSS
SUGAR BEET	$\bar{x}$	31.6	42.0	58.1	91.2	82.7	9	TM
	σ	1.10	0.97	1.93	2.01	2.54	9	MSS

N.A. not available

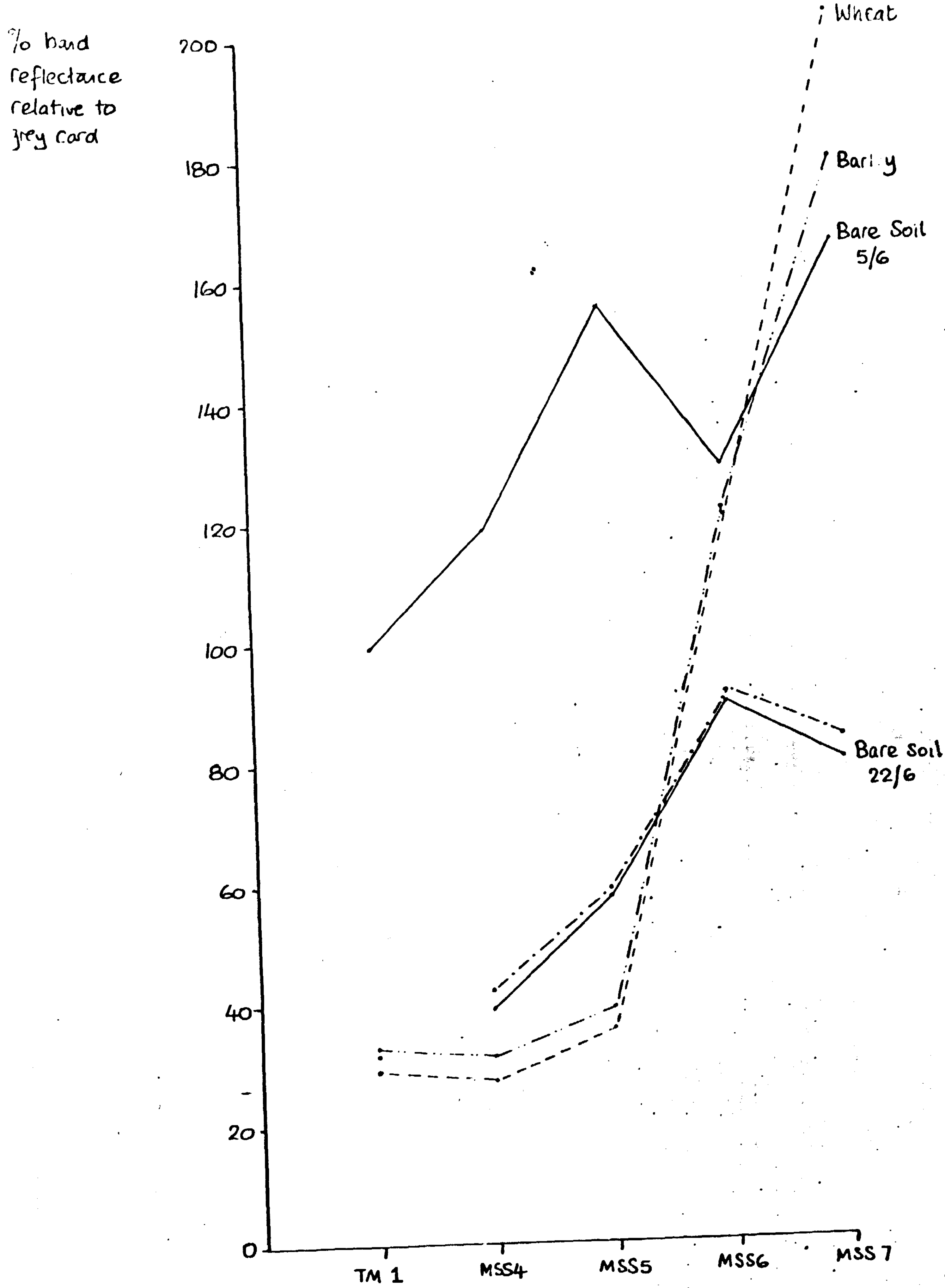

% band reflectance relative to grey card
200
180
160
140
120
100
80
60
40
20
0
TM 1
MSS4
MSS5
MSS6
MSS 7
Wheat
Barley
Bare Soil 5/6
Bare soil 22/6

Figure 7. Band reflectance for bare soil site on two seperate dates.

	TM 1	MSS 4	MSS 5	MSS 6	MSS 7
Bare Soil 5th JUNE	100	118·4	155·1	128·1	165·0
Bare Soil 22nd JUNE	–	39·6	57·8	89·1	79·8

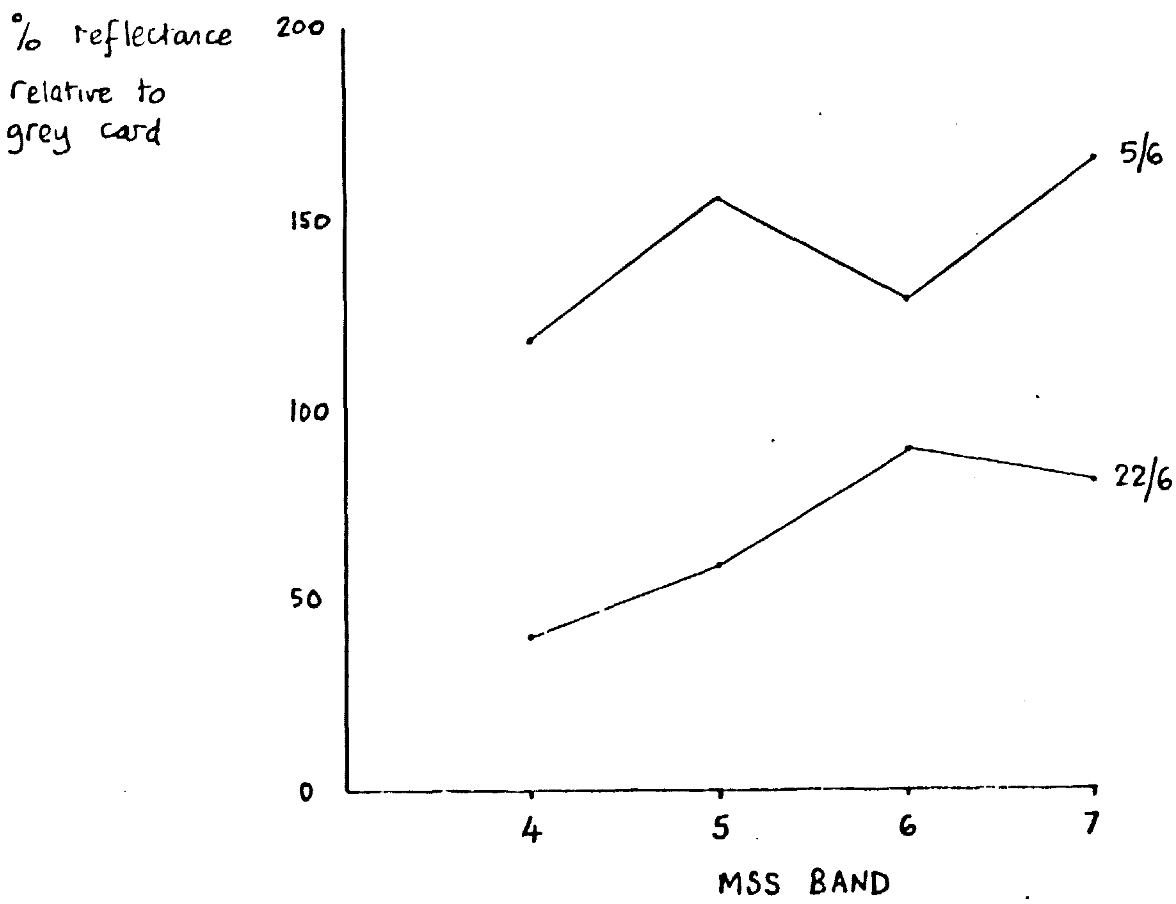


Figure [illegible]. Band reflectances for different parts of the sugar beet field.

		TM 1	MSS 4	MSS 5	MSS 6	MSS 7
Area A (Majority of field)	10YR 4/4 9 stations	31·6	42·0	58·1	91·2	82·7
Area B (Southern edge)	10YR 3/3 3 stations	26·8	33·0	44·7	83·3	70·3
	% B/A	84·8	78·6	76·9	91·3	85·0

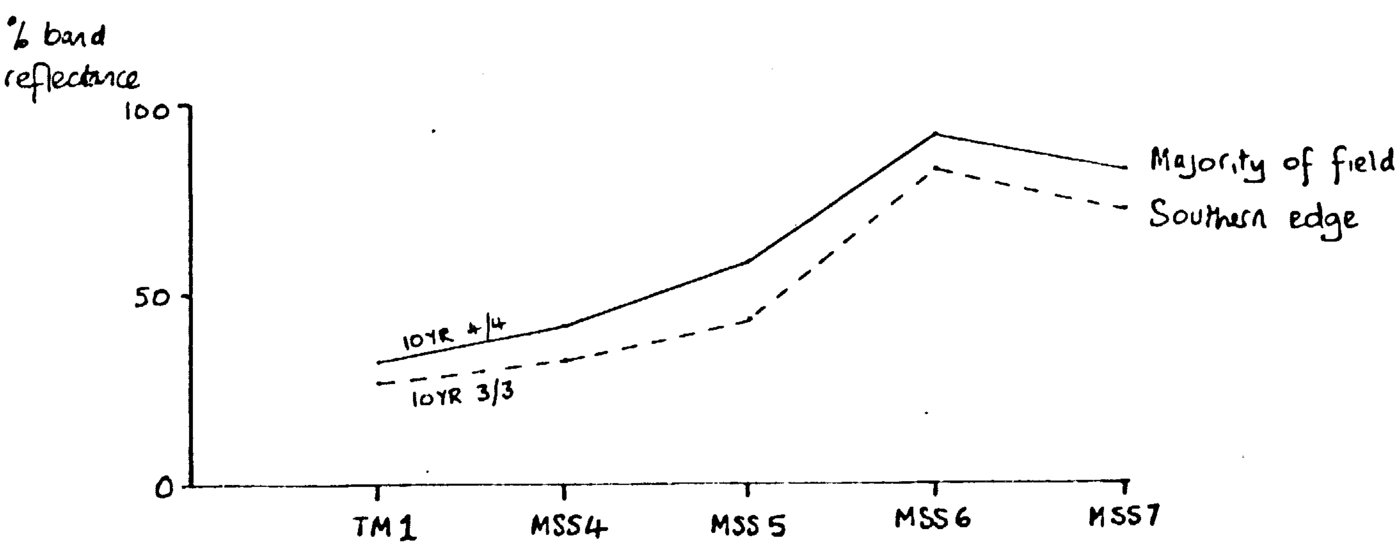


Figure 9 Calibration of FMR against Exotech 100

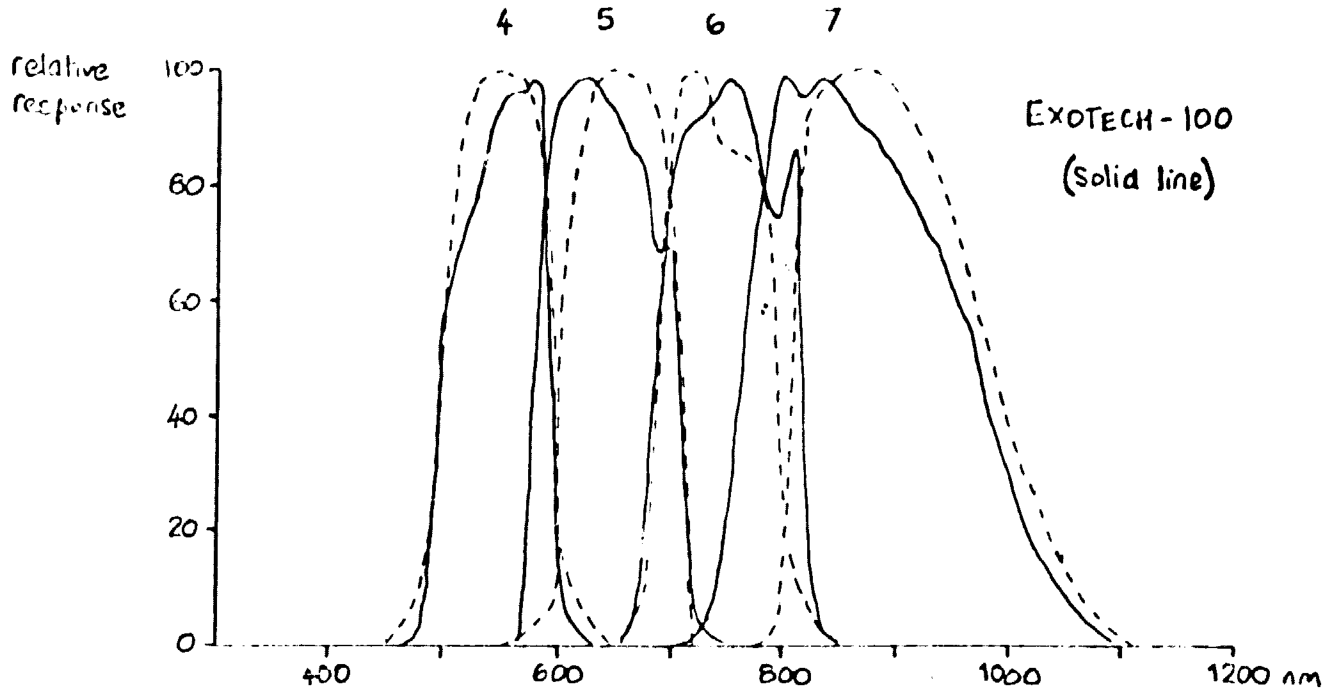
	$\bar{x}$	σ	
MSS4	0·45	0·04	
MSS 5	0·17	0·01	
MSS 6	1·53	0·15	
MSS 7	0·10	0·01	

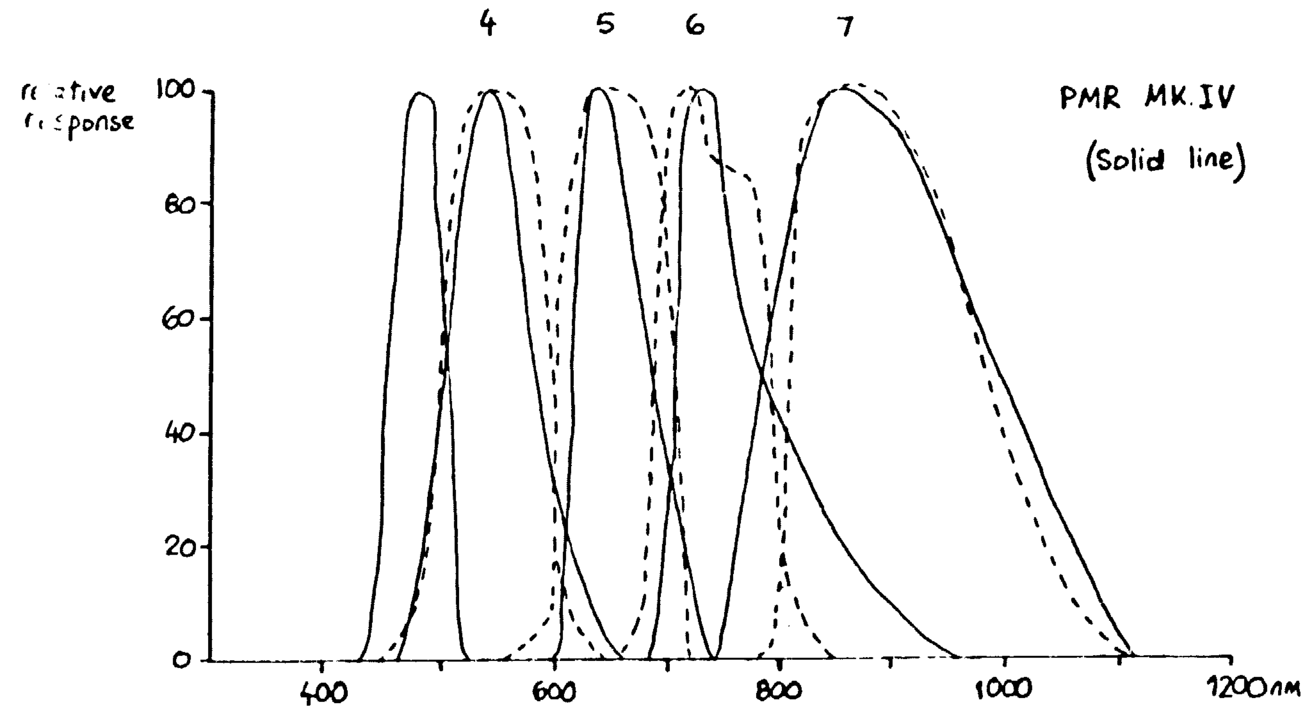
$$\text{Calibration Factor } (x) = \frac{\text{surface reflectance MSS}}{\text{surface reflectance EXOTECH}}$$

Exotech serial number : 3447

Based on data from six stations over bare soil 22/6/79

Figure 10 Spectral response of PMR MK.IV and EXOTECH-100 compared against LANDSAT MSS.





- - - - - Landsat MSS response generalised from the six sensor responses in each band

TABLE 1 - SURFACE EMISSIVITY DATA

Bare Earth

Run No.	Rb	aT^4	ε
1	7.30°C	8.55°C	0.9956
2	6.50°C	8.25°C	0.9938
3	6.65°C	8.55°C	0.9932
4	6.10°C	8.20°C	0.9925
			ε = 0.9938

Sugar Beet

1	6.05°C	6.35°C	0.9989
2	5.75°C	5.85°C	0.9996
3	5.50°C	6.20°C	0.9975
			ε = 0.9987

Barley

1	4.8°C	4.95°C	0.9995
			ε = 0.9995

Wheat

1	6.6°C	6.6°C	0.9999
2	6.6°C	6.6°C	0.9999
			ε = 0.9999

9. Leaf Water Potential

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Introduction and objectives

Transpiration losses from plants result in reduced turgor pressure, and consequently, in reduced potential energy of water in the leaves. This water loss creates an energy gradient in the water column from the soil to the root surface, through the root cortex to the root xylem and via the xylem tissue of the stem to the leaves, where water changes into the vapor phase. The transpiration process itself results from a energy gradient between the water in the leaves and the surrounding atmosphere. Thus, one can speak of a soil-plant-atmosphere continuum with respect to the gradient of decreasing free energy in water from the soil, to the plant, and out into the atmosphere (Brown, 1970).

Leaf water potential consists of at least three mutually independent components:

$$\psi_L = \psi_\pi + \psi_p + \psi_m \quad , \qquad (1)$$

where ψ_L is the total leaf water potential, ψ_π is the osmotic component, ψ_p is the pressure component (turgor potential) and ψ_m the matric component.

The osmotic component of the leaf water potential, ψ_π reduces the chemical free energy of a solution due to dissolved compounds in water (e.g. salts, sugars and other solutes). The osmotic potential of a solution is negative, and lower than the water potential of pure water which can be taken as reference.

The pressure component, ψ_p may raise or lower the total water potential. It is positiv in most plant cells, as the cell wall pressure (turgor pressure) is normally higher than atmospheric pressure, and negative in xylem vessels.

The matric potential, ψ_m represents the component of specific free energy of water which is associated with water status on interfacial borders (e.g. colloidal structures of cytoplasm, micellar structures in cell walls). The matric potential of cells is considered to be not a major component in the plant water potential.

When water potential gradients are established, water will diffuse from the region of higher free energy to a region of lower free energy, from a point of higher potential (less negative) to a point of lower potential (more negative).
During the Joint Measuring Campaign in Ruthe leaf water potential was measured on Field Nr. 4 (winter wheat). Objective of the measurements was to collect data against which the theoretically derived values from the Tergra-Model (Soer, 1977a,b) can be checked.

Methods and materials

Leaf water potential was measured using the pressure chamber technique of Scholander et al. (1965). A leaf was detached as quickly as possible and enclosed in a steel pressure chamber so that the cut end of the petiole protruded from the chamber in which it was enclosed. The chamber was then hermetically sealed, and the pressure inside was grdually increased by compressed air (0,4 bar/sec), until small sap droplets appeared on the cut surface. This could be detected with a hand-lens or, better, with a sheet of filter paper, which was put on the detached end of the petiole. By using the hand-lens we obtained values, were about 1bar higher than the values obtained with the filter paper method.

At the moment, when the xylem sap appeares on the cut end of the petiole, the applied pressure compensates the original negative pressure in intact xylem vessels. The osmotic component of the xylem sap is not measured by the pressure chamber, but its value is regarded as either constant or negligible (Boyer, 1969). In oats, for example, during previous studies we did not measure osmotic potentials of the xylem sap lower

-1bar during the whole vegetation period. Hence the applied pressure can be taken as equal to the leaf water potential.

The osmotic potential of the expressed cell sap was analyzed from the same leaves, used in the pressure chamber. The tissue was frozen in order to destroy the semi-permeability of the living cytoplasmatic membranes (i.e. turgor pressure equal zero). Then, an oil hydraulic press was used for pressing the killed leaf tissue. Discs of filter paper soaked in the expressed cell sap were used to determine the osmotic potential by a thermocouple psychrometer. The so measured osmotic potential of the expressed cell sap is regarded to correspond to the osmotic potential of the vacuolar sap in situ in the cells.

The turgor potential can easily be calculated with eq. 1:

$$\Psi_p = \Psi_L - \Psi_\pi \qquad (2)$$

Diurnal and seasonal (June 11 till June 21) measurements were carried out on Field Nr. 4 (wheat).

Results and discussion

Diurnal trends of water potential and its components

During the last decade leaf water potential has become the most widely used indicator of plant water status. In some processes like expansive growth the key parameter however is the leaf turgor potential. Therefore it is often desirable to have knowledge of both quantities. Variations in leaf pressure potential would reflect variations in leaf water potential only if the other major component, the leaf osmotic potential remained relatively constant. For this reason the osmotic potential as well as the total leaf water potential were determined.

Fig. 1 (June 12) shows the diurnal variation of leaf water potential and its components of three wheat leaves of different

insertion. Parallel to the increase in radiation intensity, the leaf water potential decreased rapidly throughout the morning till 10^{00} h. While the leaf water potential of the fourth and the fifth (flag) leaf thereafter decreased slowly to reach their minimum value of -10 (fourth) and -12 bar (flag leaf) in the afternoon, the leaf water potential of the third leaf remained constant till 15^{00} h, and had its minimum value (-8 bar) at 16^{00} h. During the evening the leaf water potential increased till they reached the morning values again (see June 11). Biscoe et al. (1976) obtained the same course and similar values of leaf water potential from their experiments with wheat.

The courses of the osmotic potential of the third and the fourth leaf are much alike. After a little decrease the leaf osmotic potential remained constant till 12^{30} h and then rapidly decreased to a minimum at 16^{00} h. The leaf osmotic pot of the flag leaf decreased rapidly till 12^{30} h and then remained constant till 16^{00} h. In the evening, after a rapid increase the osmotic potential dropped once more. Within the measuring period it did not reach the morning values (see 11 June).

This similar behavior in leaf water potential of the fourth and the fifth leaf, and the similar course in leaf osmotic potential of the third and the fourth leaf, is reflected by the leaf pressure potential. While the leaf pressure potential of the third and fifth leaf remains favorable (3 bar) at midday, it reaches values near zero in the fourth leaf.

A decrease in leaf water potential and leaf osmotic potential with height is clearly shown by Fig. 1. The difference between lower and upper leaf is smallest during the night and it reaches its maximum at midday.

Leaf water potential that develops within a plant is a function of the availability of water from the soil, the demand for water imposed by the atmosphere, and the resistance to water movement in the plant. During the Campaign in Ruthe the availability of water from the soil was not restricted because soil water potential was always high.

At sunrise plants are covered with dew. While the saturation deficit in the upper region of the plant increases rapidly, the humidity near the soil will be stored over a long time of the day, perhaps till 13^{00} h, when the osmotic potential of the third leaf decreases suddenly. On the other hand, the radiation load of the upper leaves is greater than that of the lower leaves at all times after sunrise. If there is no restriction in the availability of water from the soil, both, higher saturation deficit and greater radiation in the upper region of the canopy, will increase transpiration of the flag leaf more than that of upper leaf, so that a lower water potential is observed in the flag leaf. Begg and Turner (1970) pointed out these consequences by their experiments with tobacco.

The association between growth and turgor pressure is well known: Growth rate is promoted by an increase in turgor, when the temperature is not limiting (Acevedo 1975, Acevedo et al. 1979, Fereres 1976, Johnson and Caldwell 1976). Therefore it is favorable for the plant to maintain a positive turgor during the entire day, and especially at midday, when the leaf water potential is lowest. With a decreasing leaf water potential, this is only possible, when leaf osmotic potential drops in the same magnitude. Leaf osmotic potential can be reduced either by water loss and hence a concentration of existing solutes, or by a net increase in solutes in the tissue. Acevedo et al. (1979) and Knipling (1967) pointed out, that there is a marked accumulation of solutes in the tissue, from dawn to midday. On June 12 water potential of the flag leaf dropped about 7 bars between 6^{00} and 15^{00} h (Fig. 1). The corresponding drop in leaf osmotic potential compensated for most of the drop in leaf water potential. Leaf pressure potential remained substantially positive, so that expansive growth all over the day probably was possible. Leaf osmotic potential of the fourth and the third leaf remained constant till noon. The reason may be a reduced photosynthesis due to microclimatic factors and, perhaps, shading. Acevedo et al. (1979) showed that the sugar content of artificially shaded leaves at midday was below the observed values at dawn. On the other hand there is a large increase in total sugar level of exposed

leaves and minor increase in reducing sugars and organic acids levels.

Major resistance to water movement through the plant, generally is considered to be located, for the liquid phase, in the root, and for the vapor phase, in the stomata. Resistance to water flow in the stem xylem is considered to be very small in most plants (Slatyer, 1967). A marked resistance exists between the stem and leaf. It does not change materially with time of the day, but it is always greater in lower petioles than in the upper ones (Begg and Turner, 1970). Stomatal resistance is lower in the upper leaves and higher in the lower leaves, so that stomatal closure proceeds from the oldest leaves to the youngest (Jordan et al.,1975). This may be another reason for the decrease in leaf water potential with height.

Maintenance of turgor pressure potential over the day and over the vegetation period is an important factor for plant growth. This will be achieved by a net increase in solutes per unit of tissue. The daily course of plant water components of wheat demonstrates this clearly.

Seasonal trends of water potential

All diurnal courses of the leaf water potential of the flag leaf showed similar trends (Fig. 2). There was no severe decrease in water potential during midday due to closure of the stomata in consequence of atmospheric or soil water stress.

The daily minimum in water potential, however, was changing with time due to precipitation. During our measurements nearly 18 mm of rain were recorded between June 13 and 16. The difference in water potential minimum due to 10.7 mm precipitation on June 13 as compared to June 12 was 4 bars. The minimum measured before the rainfall was reached again two days after the last precipitation. Although minima in leaf water potential on June 12 and June 19 were similar, leaf osmotic potentials differed (Table 1).

This points to luxury transpiration on June 19. The recovery of water budget due to precipitation is still recognizable in the increase of leaf osmotic potential. This shows once more the necessity of measuring not only leaf water potentials, but their components (Acevedo et al. 1979, Fereres et al. 1978).

From 18 to 21 June high leaf water potentials of about -1 bar were measured at midnight and before dawn, when it was foggy or plants were completely dewed. In these cases transpiration was sufficiently retarded. Such low values raise the question, whether plants act as tensiometers at night. It is clear, that rooted plants do not respond directly to soil moisture content or soil water potential because of differences in root density and root structure and gradients of soil moisture content occuring throughout the rooting profile (Ritchie and Hinckley, 1975). If at all, leaf water potential will correspond to an integrated soil water potential at the total absorbing surface of the root system. This is only possible, when the soil water potential is very high and plants have time for full resaturation over night. All these conditions seem to have been fulfilled for our wheat field. This is supported by the highest water potential we measured of -0.7 bar (mean value of ten replicates) on 19 June at 06^{00} h. In general we can summarize the discussion about this question with Ritchie and Hinckley (1975): "The relationship varies with species and soil type and perhaps other factors".

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LEGEND TO THE FIGURES AND TABLES OF CHAPTER 9

Fig. 1 The leaf water potential for 3 different wheat leaves from Field Nr. 4 on June 12. Also shown are the leaf turgor and the osmotic potential. Each data point is the mean of 5 measurements.

Fig. 2 The course of the leaf water potential of the flag leaf on Field Nr. 4 between June 11 and June 22.

Table 1 The leaf osmotic potential of the 3th, 4th and 5th leaf of wheat (Field Nr. 4) before (June 12) and after heavy rainfall (June 19).

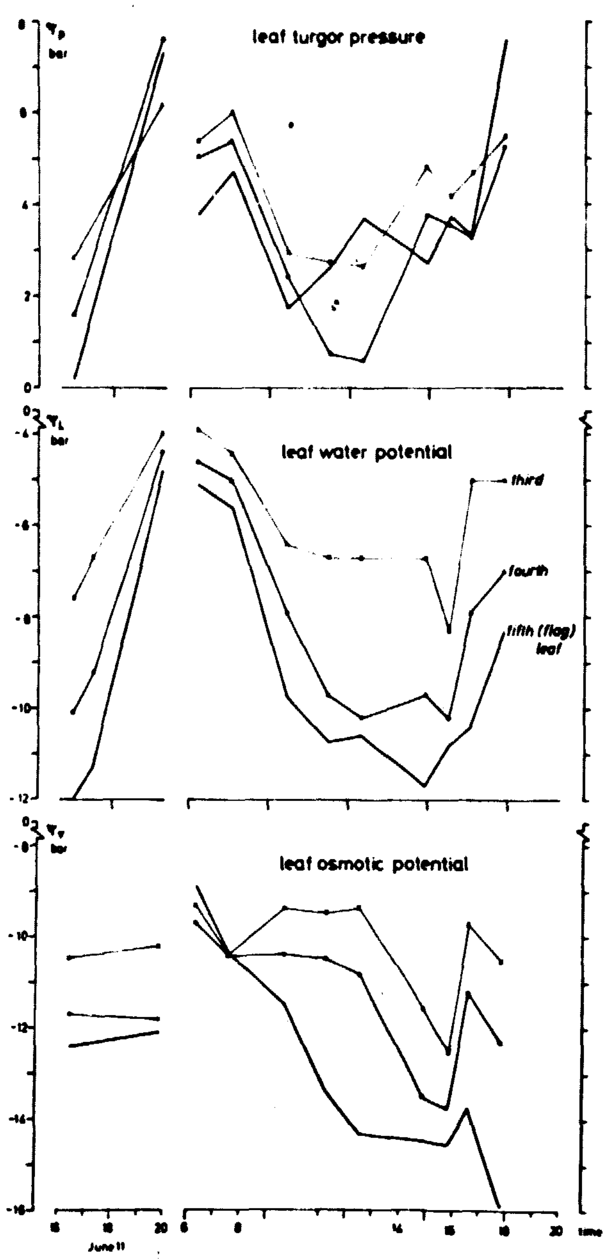

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Figure 1.

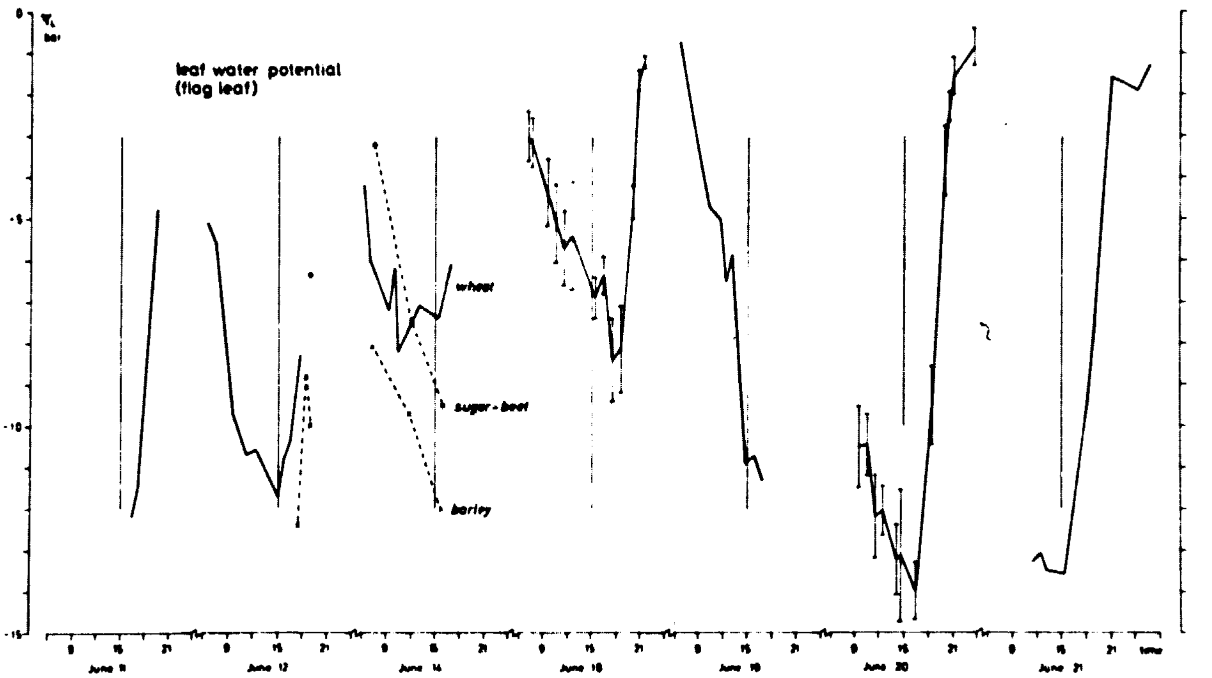

Figure 2

Table 1.

	leaf osmotic potential (bars)			
	12 June		19 June	
	1215h	1445h	1215h	1445h
third leaf	-9.4	-11.5	-5.0	-6.8
fourth leaf	-10.8	-13.5	-5.6	-9.1
fifth leaf	-14.3	-14.4	-7.6	-10.2

10. Leaf Area Index and Crop Height

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Introduction and objectives

The penetration of radiation through a plant stand depends on the amount of leaves and other plant parts obstructing the beam, on the spatial distribution and the mutual shading of leaves, on their size and orientation, etc. The detailed description of a stand's architecture is highly complicated and usually only simplified characteristics of architecture are used in radiative transfer theory. A widely accepted simplification is the assumption that a stand is horizontally uniform, i.e. the characteristics of the stand architecture and radiation do not vary within a horizontal layer and depend only on height.

The pattern of wind speed with elevation above a surface is known as the wind speed profile. Knowledge of the shape of the wind profile is necessary for two reasons. From the profile description it is possible to estimate the intensity of vertical exchange processes. With knowledge of wind speed at a fixed or reference level it is also possible to estimate wind speed at other levels. The wind speed profile is influenced by the roughness of the stand, which is a function of stand architecture. For these reasons it is necessary to use parameters characterizing the architecture of the canopy.

The simplest characteristic of the stand architecture is its heigh h measured from the ground surface ($z = 0$) to the upper level of the stand. Another widely used characteristic is the leaf area index LAI, determined as the area of leaves (upper side only) within a vertical cylinder of unit cross-section and height h. The leaf area index is a dimensionless quantity which is expressed as m^2 leaf area per m^2 ground area. To calculate the potential evapotranspiration, we have to introduce

the roughness parameter z_o in our formula. The parameter z_o is a length characteristic of the form drag at the momentum exchange surface. It depends on the shape and height of the roughness elements.

The roughness parameter z_o is near zero over very smooth surfaces: over open water, 0.02-0.6 cm; over smooth crops such as short grass, 0.6-4.0 cm. Generally, z_o increases with increasing height of the crop. From large accumulations of data in the micrometeorology literature some relationships have been developed to help estimate the magnitude of z_o. In very short crops (lawns, for example) z_o adequately describes the roughness and little adjustment is necessary.

Szeicz et al. (1969) have summarized a number of studies and related z_o to crop height (h) by

$$\log z_o = 0.997 \log h - 0.883$$

Other empirical correlations provide us with an estimate of z_o for uniform surfaces: $z_o = 0.13$ h. In tall crops z_o no longer adequately describes the roughness, and a value of d, the zero plane displacement, is needed. Stanhill (1969) fitted an expression giving zero plane displacement d as a function of the height of a wide range of crops. His data are fitted with the relation

$$\log d = 0.979 \log h - 0.154$$

For dense vegetation d can be estimated from the average crop height, h:

$$d = 0.64\ h$$

To estimate these parameters the height of the crops have to be known.

The quantity potential evapotranspiration rate $(ET)_p$ refers to the evaporation from the soil surface and the evaporation from the crop transpiration. To distinguish between these two processes the potential soil evaporation can be estimated according to Ritchie (1972):

$$E_p = \Delta/(\Delta+\gamma)\ R_n \exp(-0.398\ LAI),$$

in which expression Δ is the slope of the saturated vapour -

temperature relation, γ is the psychrometer coefficient, R_n the equivalent net radiation and LAI the leaf area index.

The potential transpiration rate T_p then can be definde as

$$T_p = (ET)_p - E_p$$

Hence for an estimation of T_p and E_p it is necessary to know LAI.

Measurements

During the Campaign in Ruthe plant height, leaf area indes and dry biomass determinations were determined for different fields and on different days. The height of the crop was measured direct in the field, with a large number of replicates. To measure the LAI we first determined the ratio between the leaf area and the dry mass of the plants. To measure the leaf area we used a Lambda Leaf Area Meter. Then we measured the dry mass of the plants harvested from different plots and calculated the leaf area index.

Results

$\bar{x}$ = arithmetic mean

s = standard deviation

n = number of measurements

P l a n t   h e i g h t s :

Date: June - 11, 1976

Field 2- Sugar beets

Single plants:	$\bar{x}$ =	16,6 cm
	s =	3,9 cm
	n =	60
Stand :	$\bar{x}$ =	18,5 cm
	s =	0,9 cm
	n =	10

Field 3 - Winter barley

Single plants:	$\bar{x}$ =	100,4 cm
	s =	9,1 cm
	n =	60
Stand :	$\bar{x}$ =	102,7 cm
	s =	2,6 cm
	n =	10

Field 4 - Winter wheat

Single plants:	$\bar{x}$ =	59,3 cm
	s =	7,8 cm
	n =	60
Stand :	$\bar{x}$ =	64,6 cm
	s =	1,7 cm
	n =	10

Field 5 - Sugar beets

Single plants :	$\bar{x}$	=	14,2	cm
	s	=	3,8	cm
	n	=	60	
Stand :	$\bar{x}$	=	15,3	cm
	s	=	1,6	cm
	n	=	10	

Field 6 - Winter barley

Single plants :	$\bar{x}$	=	103,0	cm
	s	=	6,4	cm
	n	=	60	
Stand :	$\bar{x}$	=	102,0	cm
	s	=	5,7	cm
	n	=	10	

Field 7 - Winter wheat

Single plants :	$\bar{x}$	=	59,5	cm
	s	=	9,4	cm
	n	=	60	
Stand :	$\bar{x}$	=	62,7	cm
	s	=	1,8	cm
	n	=	10	

Date: June - 21, 1978

Field 2 - Sugar beets

Single plants :	$\bar{x}$	=	24,2	cm
	s	=	4,0	cm
	n	=	50	
Single plants :	$\bar{x}$	=	27,1	cm
	s	=	2,9	cm
	n	=	25	

Field 3 - Winter barley

Single plants :	$\bar{x}$	=	102,0	cm
	s	=	10,0	cm
	n	=	60	
Stand:	$\bar{x}$	=	77,9	cm
	s	=	2,6	cm
	n	=	10	

Stand : $\bar{x}$ = 85,1 cm
s = 4,2 cm
n = 30

Field 4 - Winter wheat

Single plants : $\bar{x}$ = 74,1 cm
s = 6,8 cm
n = 50

Stand : $\bar{x}$ = 76,3 cm
s = 3,5 cm
n = 20

Date: June - 14, 1979

Ratio between leaf area and dry mass (cm^3/g):

Sugar beets : $\bar{x}$ = 140,76
s = 8,82
n = 4

Winter barley : $\bar{x}$ = 39,04
s = 3,71
n = 4

Winter wheat : $\bar{x}$ = 91,75
s = 5,47
n = 4

Measurement of plant dry mass (g/m^2):

Sugar beet :

Field 2 : $\bar{x}$ = 33,93
s = 2,34
n = 6

$\bar{x}$ = 35,0
s = 4,0
n = 3

Field 5 : $\bar{x}$ = 29,98
s = 1,94
n = 3

Winter barley:

Field 3 :

$\bar{x}$ = 772,0
s = 22,0
n = 3

$\bar{x}$ = 869,18
s = 63,11
n = 6

Field 6 :

$\bar{x}$ = 952,1
s = 90,69
n = 3

Winter wheat:

Field 4 :

$\bar{x}$ = 559,54
s = 30,0
n = 3

$\bar{x}$ = 657,42
s = 86,14
n = 6

Field 7 :

$\bar{x}$ = 675,75
s = 42,83
n = 3

Leaf area index LAI :

Sugar beets:

Field 2 : 0,48
0,49

Field 5 : 0,42

Winter barley:

Field 3 : 3,01
3,38

Field 6 : 3,72

Winter wheat:

Field 4 : 5,13
6,03

Field 7 : 6,20

Date July - 18, 1979

Sugar beets (dry mass)

Field 2: $\bar{x}$ = 539,0 g/m^2

s = 90,7

n = 6

LAI : 0,79

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11. Agrometeorological Measurements at Field Nr. 1 (Bare soil).

G. Tassone and F. Toselli
Joint Research Centre of the European Communities, Ispra

1. Introduction

It is well known that one of the main objectives of the HCMM Project is to measure the thermal inertia of soils.
Along this line a model (TELL-US) which links thermal inertia to soil humidity was developped by EARS-Holland under contract by JRC Ispra.
For the present flight experiment an area of about 150 m x 150 m was ploughed and carefully slicked in order to test this model in under flight conditions i.e. with satellite and aircraft passages at the same time.

2. Ground truth

The TELL-US model requires input of experimental data taken from about 14 hours before the maximum until the next minimum soil temperatures, say for a period of 27 hours.
The measured parameters are shown in table 7.1

Table 7.1

- soil surface temperature
- soil temperature profile (at 6 depths)
- soil heat flux (at 2 depths, 2 positions)
- soil humidity profiles
- soil physical properties
- soil albedo
- wind velocity profile (at 6 heights, up to 6m.)
- air temperature profile (at 6 heights, up to 6m.)
- air humidity profile (at 6 heights, up to 6m.)
- net radiation
- shortwave incoming radiation
- longwave incoming radiation

In order to get experimentally the soil roughness and the Bowen ratio , a mast equipped with anemometers and psychrometers was used to measure wind and humidity profiles up to 6 m.
Except soil humidity profiles and soil physical properties the data were taken automatically by a data logger for a total of 44 channels and printed on paper with scanning times between 2 and 15 minutes.

3. Data restitution

The data were collected from 13 to 22 June thus for a period longer than required by the model.
This was done to apply the model to very different wheather and soil conditions.
Unfortunately a lightning hit the 5 m mast carrying the Exotech and FRT-5 radiometers and the corresponding measurements were lost from 15,37 of the 15th to noon of 20th June.
It was then tried to get surface temperature readings by 2 thermocouples put almost at zero level and calibrated against the British PRT-5.
Tentatives were made to repair the radiometers without success.
It was then decided to replace the broken PRT-5 with the one which was already mounted on the aircraft at the Münster airport. In the visible a second Exotech was available. So it was possible to take the required radiometric measurements during the flight period, say from noon of the 20th down to 6,30 a.m. of the 22nd June.

Except for soil humidity profile and soil physical properties, all the above data were taken automatically by means of a data logger. Unfortunately they had to be printed on paper due to the temporary non availability of the incremental tape recorder used in previous campaigns. Scanning times then had to be increased, ranging between 2 and 15 minutes.
Spoiling of datais almost completed. An example at reference height (2m) is reported in table 7.2 for the day 14 June.
All the data will be available in table form in S.I. units at average hourly values.

Table 7.[illegible] Pattansen – [illegible] June [illegible] Hourly Average Values

Local time HRS	Solar Radiat. W/m2	NET Radiat. W/m2	Albedo	Atmos. Press. KPa [illegible]	Wind Veloc. m/s	Dry Air Temp. °C	Wet Air Temp. °C	Surface Temp. °C	Soil Temp. °C -0.02m	Soil Temp. °C -0.04m	Soil Temp. °C -0.08m	Soil Temp. °C -0.15m	Soil Temp. °C -0.6m	Heat Flux -0.04m W/m2
0-1	0	-73	0	1.012	1.9	13.2	12.1	12.6	12.3	14.4	15.9	17.0	15.5	-57
1-2	0	-73	0	1.012	1.8	13.0	12.4	13.9	12.5	14.1	15.4	16.7	15.5	-56
2-3	0	[illegible]	0	1.0110	3.9	12.7	11.7	13.0	12.7	14.2	15.1	16.4	15.3	-56
3-4	0	-74	0	1.0110	3.0	12.6	11.7	13.6	12.7	13.9	14.7	16.0	15.4	-53
4-5	17.5	-70	0.140	1.010	3.4	11.9	11.8	13.0	12.7	13.4	14.4	15.7	15.5	-53
5-6	20.4	-64	0.150	1.0160	3.8	12.9	11.7	13.7	12.2	13.5	14.2	15.3	15.4	-43
6-7	36.4	-51	0.140	1.0160	2.2	12.9	12.0	14.0	12.5	13.4	14.1	15.2	15.3	-33
7-8	70	-23	0.140	1.0107	2.8	13.6	12.4	14.9	13.7	13.8	14.3	15.1	15.4	-23
8-9	86	-26	0.140	1.0110	2.7	13.4	12.0	14.5	13.8	14.0	14.4	15.0	15.3	-2
9-10	[illegible]	40	0.140	1.01[illegible]	3.5	13.5	12.[illegible]	15.[illegible]	13.[illegible]	14.0	14.4	15.[illegible]	15.5	-6
10-11	[illegible]	[illegible]	0.15[illegible]	1.0098	4.3	14.4	12.5	16.3	15.0	14.[illegible]	14.4	15.[illegible]	15.5	-2
11-12	[illegible]	[illegible]	0.143	1.01[illegible]	5.8	14.5	12.6	17.[illegible]	15.4	15.0	14.3	15.[illegible]	15.3	9
12-13	[illegible]	150	0.146	1.01[illegible]	5.3	14.8	12.7	18.3	16.4	15.4	15.2	15.2	15.3	20
13-14	41[illegible]	[illegible]	0.147	1.0009	7.0	15.9	13.2	20.5	16.8	16.7	15.4	15.4	15.2	2[illegible]
14-15	465	[illegible]	0.149	1.009	6.2	16.7	13.8	21.7	20.2	18.6	18.[illegible]	15.8	15.1	36
15-16	25[illegible]	140	0.152	1.0096	3.6	16.2	13.8	18.4	19.0	18.1	18.5	16.3	15.1	15
16-17	266	150	0.160	1.0099	4.3	17.0	14.1	19.3	19.0	18.1	18.0	16.5	15.0	13
17-18	160	95	0.158	1.0086	3.7	16.1	13.8	17.1	17.6	17.4	18.0	16.7	15.1	0
18-19	98	35	0.164	1.0072	3.0	15.5	13.4	16.3	16.8	16.8	18.1	16.7	15.0	-4
19-20	44	[illegible]	0.17	1.0068	3.0	14.5	12.9	15.1	15.7	15.9	17.8	16.6	15.1	-16
20-21	0	-80	0	1.0067	4.3	10.6	11.6	13.4	14.7	15.3	17.4	16.7	15.1	-20
21-22	0	-7[illegible]	0	1.0059	3.1	13.4	11.3	10.7	13.9	14.3	16.7	16.[illegible]	15.0	-25
22-23	0	-83	0	1.0054	1.3	12.5	11.6	12.5	13.5	13.9	16.3	15.5	15.0	-2[illegible]
23-24	0	-80	0	1.0054	2.5	12.7	11.5	10.3	13.0	13.7	15.9	15.4	15.0	-20

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12. Agrometeorological Measurements on Fields Nr. 2 and 3

J. von Hoyningen-Huene, H. Fussy, H. Goedecke and H. Braden[1)]

1. Introduction

The Central Agrometeorological Research Institute (ZAMF) of the German Weather Service at Braunschweig/Germany, is engaged in several investigation programmes concerning evapotranspiration processes for canopies, as e.g. the water demand of plants [2)], and energy budget as related to plant productivity [3)]. Stimulated by the conferences on evapotranspiration of the World Meteorological Organization (WMO) and of the International Commission on Irrigation and Drainage (ICID) 1977 at Budapest, investigations on assessment of areal evapotranspiration were taken up additionally. Preliminary studies showed the urgent need for new methods of assessment of both, point and areal evapotranspiration. In this situation the Joint Measuring Campaign (JMC carried out by Joint Research, Centre IRC of the Commission of the European Communities, Ispra, Italy) offered the chance of combining efforts in the three fields, investigation of energy budget of plants, consumptive water use of different canopies at the same time, and telemetric assessment of areal evapotranspiration in order to develop approaches to assess the areal evapotranspiration of inhomogeneous terrains, regarding the actual water use of the different parts, due to their different heat budget.

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2) Promoted by Deutsche Forschungsgemeinschaft DFG 189 Schr.

3) Promoted by Deutscher Wetterdienst

4) The authors wish to thank the J.R.C. for its financial support of the experiment.

Micrometeorological investigations on sugar beets (site II), barley (site III), wheat and grass [illegible], JRC's Joint Measuring Campaign [illegible] ([illegible]).

J. v. Hoyningen-Huene, H. Goedecke, H. [illegible] and H. Braden[1])

1. Introduction

The Central Agrometeorological Research Institute (ZAMF) of the German Weather Service at Braunschweig/Germany, is engaged in several investigation programmes concerning evapotranspiration processes for canopies, as e.g. the water demand of plants [2]), and energy budget as related to plant productivity [3]). Stimulated by the conferences on evapotranspiration of the World Meteorological Organization (WMO) and of the International Commission on Irrigation and Drainage (ICID) 1977 at Budapest, investigations on assessment of areal evapotranspiration were taken up additionally. Preliminary studies showed the urgent need for new methods of assessment of both, point and areal evapotranspiration. In this situation the Joint Measuring Campaign (JMC carried out by Joint Research, Centre IRC of the Commission of the European Communities, Ispra, Italy) offered the chance of combining efforts in the three fields, investigation of energy budget of plants, consumptive water use of different canopies at the same time, and telemetric assessment of areal evapotranspiration in order to develop approaches to assess the areal evapotranspiration of inhomogeneous terrains, regarding the actual water use of the different parts, due to their different heat budget.

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[illegible]

The measurements were carried out at two places, 4o km apart. Site I, and III at Ruthe are situated about 2o km south of Hannover on typical loess-soil of the "Hildesheimer Boerde" (VAN DER PLOEG et al., 1979), the fields in Völkenrode near Braunschweig, consist of loamy sand soil.

When the campaign was started, winter barley (height 11o cm, 148 plants per squaremeter) had ended flowering, and the sugar beet plants covered only 15% of the soil, while the wheat canopy had reached the phenological state of earing at August 15. At the end of JMC, the barley started ripening, the wheat began flowering and the sugar beet plants covered 64% of the soil. The grassland always was kept short (5-1o cm). At all four sites, heat budget measuring stations were established, consisting of a net radiation meter, a soil heat flux plate, and two psychrometers with dry and wet bulb thermometers. The platinum resistance thermometers of the Völkenrode experiments were fixed in a difference measurement bridge, those in Ruthe in a WHEATSTONE bridge. The wind velocity at all sites was measured by different cup anemometers, and the potential evaporation by ceramic evaporimeters. (V. HOYNINGEN-HUENE, 1979). In Völkenrode the actual evapotranspiration of the wheat canopy additionally was measured using two 3 m^2 weighable suctionlysimeters (V.HOYNINGEN-HUENE ,and BRAMM, 1978). Global radiation Rg and short wave reflection Rr was measured at the sites in Völkenrode only. Two infrared thermometers (HEIMANN KT 24) were used to determine the surface temperatures t_o of sugar beet and barley during the measurement flights of the DFVLR aircraft and the HCMM satellite from June 2o - 22. The measurements were recorded by an on-line computer in Völkenrode, gaining 72o measurements per hour, and printing mean results in 15 minutes intervals. In the fields of Ruthe analogue compensating recorders were used, taking 3o measurements per hour for every probe. The data were converted by a semi automatic digitalizer.

The thermal characteristics of the soils were measured with a heated thermoneedle. The stomatal resistances had to be calculated from diffusion measurements using a porometer.

The evaluation of actual evapotranspiration E, latent heat 1E and sensible heat flux H was carried out according to a form of the SVERDRUP-BOWEN-approach, derived from the heat budget equation

$$Rn + G + H + 1E = 0 \qquad (1)$$

and from the transport equations for sensible heat flux H

$$H = k_H \rho \ c_p \frac{\partial t}{\partial z} = \frac{\rho \ c_p}{r_a} \qquad (2a)$$

and that for the flux of latent enthalpy 1E

$$1E = -k_E \ \rho \frac{\partial e}{\partial z} \cdot \frac{0{,}623 \ 1}{p} = \frac{\rho}{p} \frac{0{,}623 \ . \ 1 \ . \ \Delta e}{(r_i + r_a)} \qquad (2b)$$

Then the form of the SVERDRUP-equation becomes

$$1E = - (Rn + G) \ . \ (1 - \frac{\gamma}{s + \gamma} \quad \frac{\Delta t}{\Delta t'}) \qquad (3)$$

The resistances in eq. (2) consist of a boundary layer resistance r_a and an interior bulk resistance r_i, composed of a leaf stomatal resistance r_{St} and a canopy resistance r_c.

(G= soil heat flux, s = slope of water vapour pressure-curve, γ = psychrometer constant, Δt = dry bulb temperature-difference of two heights above the canopies, $\Delta t'$ = wet bulb temperature difference of the same levels).
The reliability of this approach was shown by v.HOYNINGEN-HUENE and BRADEN (1978).
Due to the good agreement, under most conditions, between the absolutely different lysimetry and heat budget method, the authors recommended the Bowen ratio method for both, short and long time investigations.

Only in the case of wet bulb temperature gradients smaller than o,2 K, small measurement errors cause high deviations in the evaporation results. Consequently in such cases the latent enthalpy lE was calculated assording to the "equilibrium evaporation formula" (MCILROY 1977)

$$lE = \frac{s}{s + \gamma} \quad (Rn + G), \qquad (4)$$

which yields acceptable estimations of evaporation if the fields are large and uniform and if actual is not far from potential evapotranspiration.

3. Results

During the period of JMC most of the days were overcast and rainy. A short clear weather period was on June 1oth and from Juni 2oth to 22th. Consequently the results of the micrometeorological investigations will be discussed comprehensively for the whole period, and in detail for the last two days, of the flight measurement programm only.

3.1 Heat budget and evapotranspiration during the measuring campaign (June 1o to June 22)

The hourly values of air temperatures and humidities of site II and III are listed in Tab. 1. The daily sums and means of heat budget and evapotranspiration are shown in Tab. 2a, 2b and 2c.

As shown in the upper part of Fig. 1, the run of the daily sums of actual evapotranspiration of barley and sugar beet and potential evaporation of the ceramic disc agree well even though the sugar beets were very small in the first days and grew very fast during the campaign (the soil covering percentage increased from 15 to 64%).
Remarkable differences are found only on warmer days, as June 9 or 21. On the contrary during the whole period the consumptive water use of the wheat plot in Braunschweig is much higher.

This is caused by the phenological stage of the wheat, earing at June 15, inducing high aerodynamical roughness, low albedo (12%), high shortwave radiation uptake and high physiological water demand.

At the same time the barley crop had already finished flowering. The horizontal shape of ears and awns induced a less turbulent airflow above the canopy and reduced eddy diffusivity in the canopy (consequently increasing the bulk resistance). At the same time, the brighter colour of the ripening plants reduced the radiation uptake (Fig. 1, lower part). Due to frequent rainfall, the wet upper layers of the sugarbeet plot were able to compensate the low transpiration rate of the small plants by soil evaporation. The high radiation uptake of the dark soil additionally induced an increase of the evapotranspiration to such an extend, that it was similar to the values of the barley plot and of the evaporimeter.

The mean sensible heat fluxes H (Tab. 2a and 2b) were very low. On cool days they exceeded the fluxes of latent enthalpy lE and on clear days they scarcely obtained 5% of lE. The part of the energy budget which was used for soil heat flux at site II was about 5-1o% due to the low leaf area and was constantly lower (o,5-5 %) beneath the dense barley canopy.

3.2 Heat budget and evapotranspiration during flight measurement programm

From June 2o-22 complete heat budget measurements were taken additionally from two other canopies in order to get comprehensive comparisons of sugar beet (Tab. 3), barley (Tab. 4) winter wheat (Tab. 5) and grass (Tab. 6); some of them are plotted in Fig. 2. In spite of a relative high albedo (18%), the short cut lawn uses the radiation energy most efficiently for transpiration, the sugar beet plot comes second due to the dark colour and the cool open soil surface(low)longwave radiation emission),followed by the wheat canopy, while barley ranges last due to its high shortwave reflectivity and high longwave eradiation. The relatively low radiation energy gain of the wheat crop is supposed to be caused by the low density (LAI = 2,55) and high longwave eradiation of the dry and warm soil surface.

In spite of a low leaf area index, wheat evapotranspirates most. It is followed by grass and sugar beet, while barly has again the lowest rates. The reason of these differences can be seen best on June 21. The daily runs are quite undisturbed, except by some clouds at about 11 a.m. at Ruthe and 12 a.m. at Völkenrode.
The barley canopy reduces its transpiration already in the morning hours, while grass, sugar beet and wheat have equal evapotranspiration rates nearly until noon. Because of the drying soil surface, the young sugar beet crop (6o% soil coverage) reduces its actual evapotranspiration ETA from 11.oo a.m., and the grass from 2p.m., when the wheat crop has its maximum transpiration.

Due to the relatively low net radiation, the energy required for the evapotranspiration of the wet plot was partly taken from sensible heat flux H, which is positive from the late morning hours on.

4. The effect of biophysical interactions upon telemetrical assessment of actual evapotranspiration

The surface temperatures and the stomatal resistances of the sugar beet and barley canopies, as measured on June 21th and 22 nd, are listed in Tab. 8,9,1o and 11. Both parameters hardly deviate between both crops because the differences in evapotranspiration were not caused by water shortage, but by the morphology of the stand, by physiological processes, and by their effects upon heat exchange processes. If there are differences, they are observed already in the morning hours. On the contrary, reductions of evapotranspiration, caused by poor water supply in the soil, become effective only in later hours, which can be seen in case of the grass canopy. That phenomenon was shown in more striking cases by V.HOYNINGEN-HUENE (1977). The reduction is mostly induced by stomatal closure. Then the leaf temperatures, the sensible heat flux, and the Bowen-ratio must increase. Vice versa water stress can easily be recognised from high surface temperatures.

If differences in evapotranspiration are not caused by water shortage, but by other processes, as in the four plots described above, additional measurements are necessary in order to calculate evapotranspiration form telemetric data due to methods describd by SOER (1977) and by V. HOYNINGEN-HUENE (1977). According to equation (2b) the basic equation is

$$E = \text{const} \cdot \frac{e_a - E(t_o)}{r_i + r_a} \cdot \qquad (5)$$

where e_a is the water vapour pressure of the air at the temperature t_a and $E(t_o)$, the saturation vapour pressure can be calculated from the telemetrically abtained canopy temperature too. Besides the actual humidity of the air, which can easily be measured (e.g. by a meteorological network), knowledge about the resistance is necessary.

If the radiation balance is known, some information about those resistances, particularly about r_a (the reciprocal turbulent diffusivity), can be obtained. From the equation 1 to 3, the relations between Bowen-ration $\beta = H/L$ can be found:

$$\frac{r_a + r_i}{r_a} = \text{const} \; \beta \cdot \frac{E(t_o)\; e_a}{t_o - t_a} \cdot \qquad (6)$$

or:

$$t_o - t_a = \frac{(R_n + G) r_a}{(\beta^{-1} + 1)} \cdot \text{const} \qquad (7)$$

For dense crops, an estimation of the soil heat flux from the radiation balance is sufficient, but there remains the problem of the estimation either of the Bowen-ratic or of the internal resistance (e.g. as a function of soil moisture). The calculation of r_a from wind profile measurements, as measured near the soil, and atmospheric stability, is very difficult too. Further investigations in this field are necessary in the future. If no analytical solutions are possible, iteration methods, as described by SOER (1977), should be applied.

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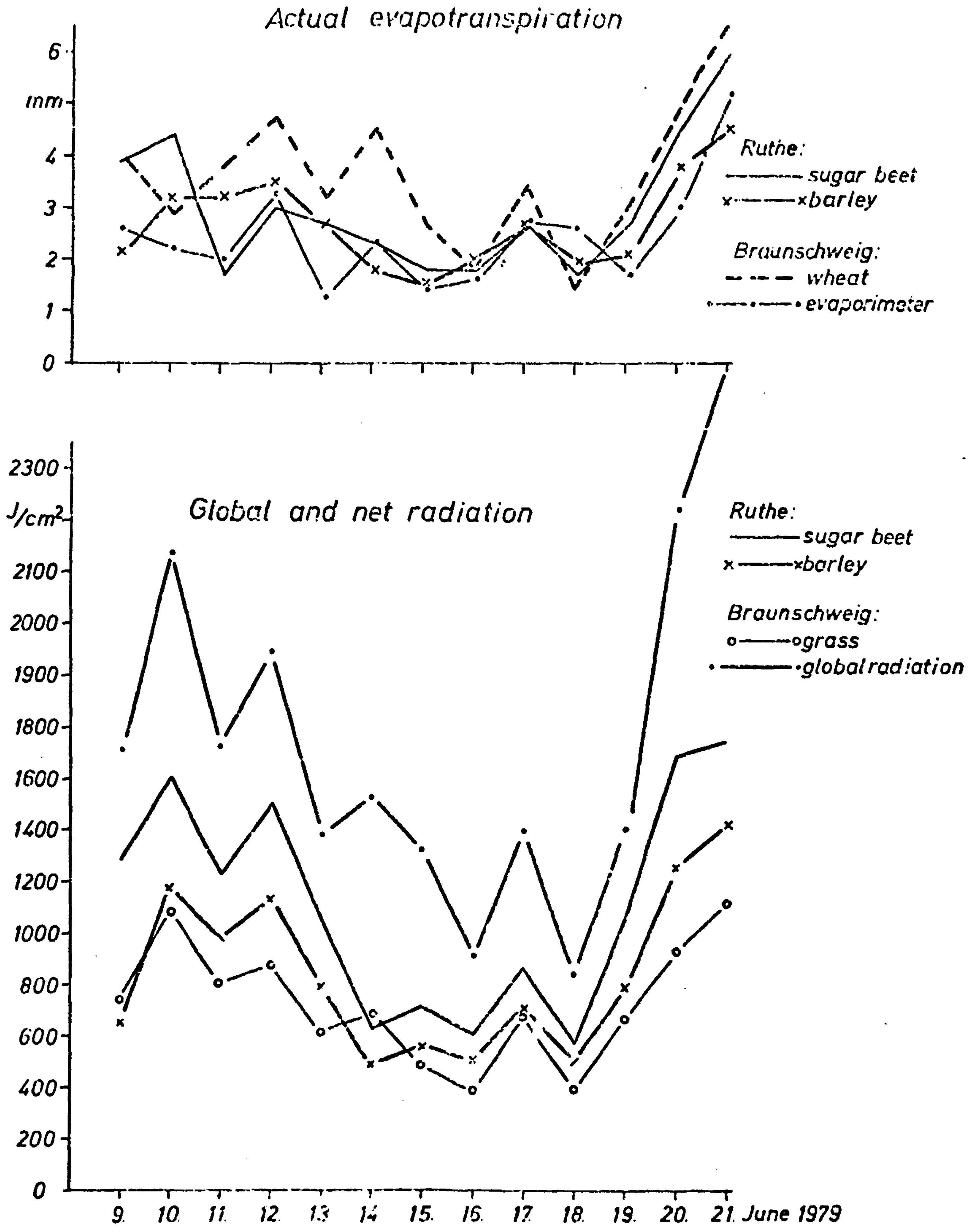

Fig. 1: Daily sums of evapotranspiration (upper part) and radiation (lower part) of different crops Ruthe and Völkenrode June 9 - 21 1979.

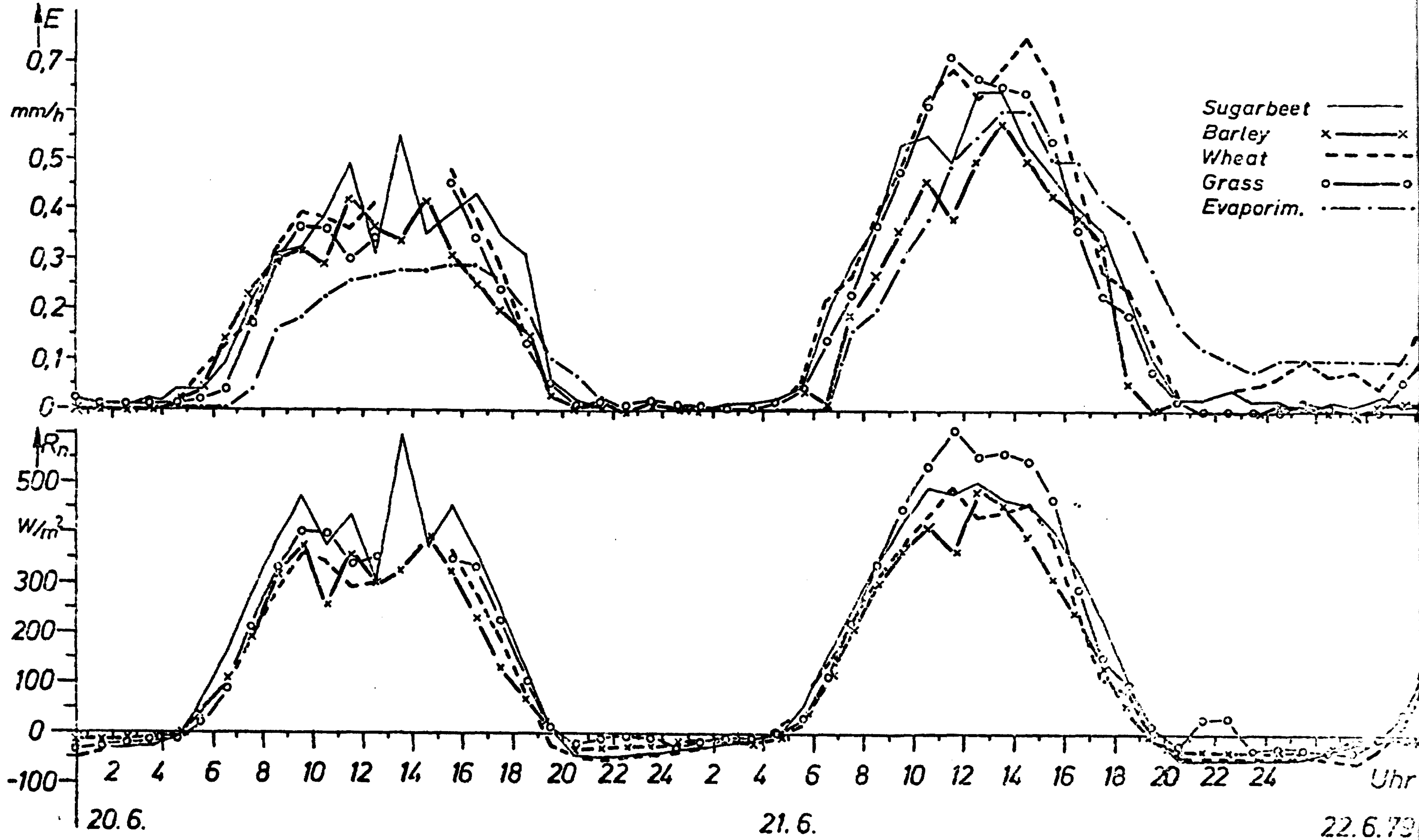

Fig. 2: Daily runs of evapotranspiration and radiation of different crops. Ruthe and Völkenrode, June 20 - 22 1979.

List of tables

Tab. 1: Hourly values of air temperatures t and water vapour pressures e, Ruthe, Site II (Sugar beets) and Site III (barley) June 8 - 19

Indices: u = lower level, 50 cm at site II
120 cm at site III

o = upper level; 200 cm at site II
240 cm at site III

Date 08.06.1979

Hour (MEZ)	Site II t_u °C	t_o °C	e_u mbar	e_o mbar	Site III t_u °C	t_o °C	e_u mbar	e_o mbar
13.00 - 14.00	15.5	15.3	12.1	11.3	14.2	14.9	12.6	11.4
14.00 - 15.00	15.1	15.0	12.2	11.3	14.9	14.7	11.8	11.2
15.00 - 16.00	16.0	15.7	12.2	11.1	15.4	15.2	12.0	11.4
16.00 - 17.00	16.0	15.8	12.2	11.3	15.3	15.4	12.0	11.3
17.00 - 18.00	15.1	15.1	12.1	11.4	14.2	14.7	12.0	11.1
18.00 - 19.00	13.6	13.5	12.9	12.6	12.8	13.0	12.8	12.4
19.00 - 20.00	12.3	12.4	12.8	12.5	11.2	11.7	12.5	12.0
20.00 - 21.00	11.8	11.7	12.4	12.0	11.1	11.1	11.7	11.6
21.00 - 22.00	10.9	10.9	12.2	11.9	9.9	10.5	11.6	11.4
22.00 - 23.00	11.4	11.5	12.4	12.0	10.4	10.9	11.9	11.6
23.00 - 24.00	11.4	11.4	12.7	12.4	10.6	11.0	12.1	11.8

Tab. 1: Cont.

Date 09.06.1979	Site II				Site III			
Hour (MEZ)	t_u °C	t_o °C	e_u mbar	e_o mbar	t_u °C	t_o °C	e_u mbar	e_o mbar
00.00 - 01.00	11.8	12.0	12.5	12.1	10.8	11.2	12.9	11.9
01.00 - 02.00	11.8	12.0	12.7	12.0	10.9	11.3	13.0	11.8
02.00 - 03.00	11.3	11.5	12.0	12.1	10.3	11.2	11.8	11.3
03.00 - 04.00	10.9	11.2	11.8	11.8	9.6	10.4	11.8	11.4
04.00 - 05.00	11.6	11.9	12.0	11.4	10.6	11.2	11.9	11.3
05.00 - 06.00	11.6	11.9	12.1	11.8	10.8	11.1	12.0	11.7
06.00 - 07.00	11.7	11.7	12.7	12.3	11.0	11.1	12.5	12.1
07.00 - 08.00	11.9	11.9	13.0	12.6	11.2	11.4	12.8	12.4
08.00 - 09.00	11.9	11.8	13.2	12.8	11.3	11.5	12.9	12.6
09.00 - 10.00	12.5	12.3	13.5	13.2	12.1	12.0	13.6	13.1
10.00 - 11.00	14.4	14.0	14.6	13.7	14.5	13.9	14.6	14.0
11.00 - 12.00	16.0	15.5	14.7	13.5	16.2	15.6	14.6	13.6
12.00 - 13.00	17.4	16.9	14.4	12.9	17.1	16.7	14.0	13.4
13.00 - 14.00	18.0	17.4	13.4	12.7	16.9	16.7	13.4	12.8
14.00 - 15.00	18.8	18.4	13.4	12.1	18.2	17.8	13.7	12.9
15.00 - 16.00	18.8	18.5	13.2	12.4	17.6	17.7	13.4	12.8
16.00 - 17.00	17.9	18.1	13.4	12.6	16.9	17.3	13.8	13.0
17.00 - 18.00	17.8	18.1	13.6	12.8	16.9	17.3	13.7	13.1
18.00 - 19.00	17.6	17.6	13.5	12.9	16.2	16.7	13.8	13.3
19.00 - 20.00	15.7	16.1	14.1	13.5	14.5	14.9	13.7	14.3
20.00 - 21.00	13.3	13.6	14.0	13.9	12.1	12.9	13.4	13.5
21.00 - 22.00	12.9	13.2	13.2	13.1	11.6	12.3	12.9	13.0
22.00 - 23.00	13.0	13.2	13.4	13.2	11.9	12.3	13.2	13.1
23.00 - 24.00	12.8	12.9	13.4	13.2	11.6	12.0	13.1	12.8

Tab. 1: Cont.

Date 10.06.1979	Site II				Site III			
Hour (MEZ)	t_u °C	t_o °C	e_u mbar	e_o mbar	t_u °C	t_o °C	e_u mbar	e_o mbar
00.00 - 01.00	11.7	11.8	12.7	12.2	10.5	10.8	12.3	11.9
01.00 - 02.00	10.5	10.5	11.8	11.9	9.3	9.6	11.4	11.5
02.00 - 03.00	10.9	10.9	12.2	11.9	10.1	10.2	11.9	11.8
03.00 - 04.00	10.8	10.8	11.9	11.6	9.8	10.2	11.7	11.4
04.00 - 05.00	10.3	10.3	11.2	10.9	9.4	9.6	11.0	10.7
05.00 - 06.00	10.5	10.5	10.7	10.5	9.8	9.9	10.6	10.3
06.00 - 07.00	11.0	11.0	10.9	10.3	10.2	10.5	10.9	10.5
07.00 - 08.00	11.7	11.7	10.8	10.1	11.1	10.9	10.7	10.3
08.00 - 09.00	11.8	11.9	10.7	9.9	11.5	11.2	10.8	10.5
09.00 - 10.00	12.3	12.3	10.7	9.9	12.5	11.8	10.9	10.1
10.00 - 11.00	13.1	13.1	10.8	9.8	13.2	12.6	11.1	10.6
11.00 - 12.00	14.2	14.1	11.2	10.3	14.0	13.4	12.0	11.1
12.00 - 13.00	15.6	14.9	11.7	11.0	15.5	14.7	12.5	11.6
13.00 - 14.00	16 5	16.1	11.8	10.4	16.5	15.9	12.4	11.4
14.00 - 15.00	17.1	16.2	12.0	11.4	16.4	15.7	12.9	12.0
15.00 - 16.00	17.2	16.7	11.5	11.2	16.9	16.2	12.7	12.1
16.00 - 17.00	17.7	17.3	11.8	11.1	16.9	16.6	12.8	11.8
17.00 - 18.00	17.6	17.3	11.4	11.0	16.6	16.4	12.7	12.0
18.00 - 19.00	17.2	16.9	11.6	11.3	15.4	15.7	12.2	11.3
19.00 - 20.00	15.7	15.8	12.2	11.8	13.3	14.6	12.4	11.5
20.00 - 21.00	13.4	14.4	12.2	11.6	11.0	13.8	11.6	11.2
21.00 - 22.00	11.8	13.2	11.9	11.5	9.2	12.4	10.9	11.1
22.00 - 23.00	12.3	12.3	11.7	11.9	8.2	11.7	10.3	10.7
23.00 - 24.00	10.8	11.4	11.3	11.4	8.8	10.7	10.7	10.8

Tab. 1: Cont.

Date 11.06.1979

Hour (MEZ)	Site II t_u °C	t_o °C	e_u mbar	e_o mbar	Site III t_u °C	t_o °C	e_u mbar	e_o mbar
00.00 - 01.00	10.5	11.0	11.5	11.4	8.9	9.7	10.9	10.8
01.00 - 02.00	10.4	10.6	11.3	11.4	8.8	9.5	10.9	10.9
02.00 - 03.00	10.2	10.3	11.2	11.3	8.8	9.3	10.8	10.8
03.00 - 04.00	10.2	10.4	11.2	11.5	8.8	9.2	10.8	10.9
04.00 - 05.00	10.2	10.3	11.7	11.5	9.0	9.3	11.2	11.3
05.00 - 06.00	11.2	11.1	12.3	12.0	10.2	10.4	12.1	11.7
06.00 - 07.00	12.2	12.0	12.7	12.5	11.3	11.3	12.5	12.1
07.00 - 08.00	12.8	12.7	13.3	13.0	12.1	12.1	13.1	12.7
08.00 - 09.00	13.7	13.4	13.9	13.6	13.0	12.9	13.7	13.4
09.00 - 10.00	14.6	14.3	14.4	14.1	14.0	13.9	15.0	14.0
10.00 - 11.00	16.2	15.8	15.4	15.0	15.7	15.4	15.5	14.9
11.00 - 12.00	19.3	18.3	16.9	16.3	19.0	18.3	17.6	16.8
12.00 - 13.00	21.6	20.9	17.9	17.6	20.7	20.3	19.6	18.3
13.00 - 14.00	22.6	21.9	17.9	17.9	21.7	21.3	19.7	18.7
14.00 - 15.00	24.3	23.7	17.6	17.6	22.9	22.7	18.8	18.1
15.00 - 16.00	24.3	23.8	17.5	17.2	22.9	23.0	19.7	18.0
16.00 - 17.00	24.7	24.4	17.7	17.0	23.5	23.4	19.8	18.1
17.00 - 18.00	24.7	24.5	18.5	18.0	23.0	23.2	20.8	19.2
18.00 - 19.00	23.6	23.5	19.6	19.4	21.6	22.2	20.7	19.8
19.00 - 20.00	22.3	22.7	19.9	19.2	19.9	21.1	20.7	19.1
20.00 - 21.00	19.6	20.1	19.6	19.8	17.4	19.0	18.6	18.8
21.00 - 22.00	18.3	18.6	18.1	18.3	16.6	17.4	17.4	17.8
22.00 - 23.00	17.5	17.3	17.0	18.1	16.2	16.8	17.0	16.7
23.00 - 24.00	16.5	16.7	16.1	16.4	15.0	15.7	15.9	15.7

Tab. 1: Cont.

Date 12.06.1979	Site II				Site III			
Hour (MEZ)	t_u °C	t_o °C	e_u mbar	e_o mbar	t_u °C	t_o °C	e_u mbar	e_o mbar
00.00 - 01.00	15.2	15.8	15.5	15.7	13.7	14.7	14.9	14.9
01.00 - 02.00	14.4	14.7	15.5	15.5	12.2	14.0	14.1	14.8
02.00 - 03.00	13.6	14.0	15.2	15.0	12.0	13.2	14.0	14.6
03.00 - 04.00	14.4	14.4	15.3	15.6	13.1	13.7	15.1	15.0
04.00 - 05.00	14.5	14.5	15.6	15.7	13.4	13.8	15.3	15.2
05.00 - 06.00	14.6	14.6	15.6	15.7	13.3	13.7	15.2	15.0
06.00 - 07.00	16.0	16.0	16.6	16.4	15.1	15.4	16.6	16.2
07.00 - 08.00	17.7	17.7	16.6	16.3	17.0	17.2	16.6	16.0
08.00 - 09.00	18.7	18.5	16.3	15.7	18.2	18.2	16.4	15.8
09.00 - 10.00	20.3	19.7	16.2	15.4	19.5	19.4	16.6	15.9
10.00 - 11.00	20.5	19.9	16.0	15.4	19.4	19.2	16.6	15.9
11.00 - 12.00	21.2	20.3	15.7	15.2	20.1	19.6	16.4	15.8
12.00 - 13.00	21.3	20.3	15.3	14.6	19.9	19.6	15.6	15.1
13.00 - 14.00	21.8	20.9	14.8	14.0	20.2	19.9	15.3	14.8
14.00 - 15.00	21.9	20.9	14.7	13.8	20.2	19.9	15.5	14.9
15.00 - 16.00	21.1	20.2	15.0	14.4	19.5	19.0	15.6	15.3
16.00 - 17.00	20.1	19.9	14.3	13.7	18.2	18.1	14.7	14.2
17.00 - 18.00	18.4	17.9	13.6	13.3	16.6	16.8	14.0	13.6
18.00 - 19.00	17.6	17.4	14.1	13.3	15.9	16.2	13.9	13.6
19.00 - 20.00	15.7	15.8	14.3	13.9	14.0	14.5	14.1	13.8
20.00 - 21.00	13.9	13.9	14.0	13.8	11.9	12.5	13.5	13.5
21.00 - 22.00	12.7	12.7	13.5	13.4	11.1	11.5	12.7	12.8
22.00 - 23.00	11.8	11.9	12.9	12.7	10.1	11.2	12.1	12.3
23.00 - 24.00	12.2	12.4	13.4	13.0	10.9	11.6	12.5	12.8

Tab. 1: Cont.

Date 13.06.1979	Site II				Site III			
Hour (MEZ)	t_u °C	t_o °C	e_u mbar	e_o mbar	t_u °C	t_o °C	e_u mbar	e_o mbar
00.00 - 01.00	12.9	12.8	13.7	13.6	11.9	12.1	13.7	13.3
01.00 - 02.00	12.9	12.7	13.3	13.3	11.9	12.1	13.5	13.0
02.00 - 03.00	12.9	12.7	13.4	13.4	12.1	12.0	13.5	13.3
03.00 - 04.00	12.7	12.5	13.4	13.3	11.6	11.8	13.2	13.0
04.00 - 05.00	12.4	12.3	13.4	13.3	11.6	11.7	13.1	12.9
05.00 - 06.00	12.6	12.4	13.2	13.2	11.7	11.8	13.1	13.0
06.00 - 07.00	12.5	12.4	13.5	13.3	11.8	11.8	13.2	13.0
07.00 - 08.00	12.3	12.2	13.7	13.5	11.5	11.6	13.4	13.1
08.00 - 09.00	13.2	13.3	14.3	13.5	12.9	12.6	14.6	13.8
09.00 - 10.00	14.3	13.8	14.6	14.1	13.5	13.3	14.5	14.0
10.00 - 11.00	15.3	14.2	15.1	14.7	15.4	14.9	16.0	15.1
11.00 - 12.00	17.3	17.0	16.2	15.4	17.1	16.6	16.5	15.8
12.00 - 13.00	18.7	18.2	17.0	15.7	18.3	18.1	17.1	16.0
13.00 - 14.00	18.7	18.0	16.6	15.6	18.2	17.8	16.6	15.8
14.00 - 15.00	18.8	18.4	16.4	15.5	17.9	17.8	16,6	15.5
15.00 - 16.00	16.5	16.5	16.3	15.6	15.2	15.5	16.4	15,7
16.00 - 17.00	16.6	16.3	16.8	16.1	16.0	15.9	16.7	16.2
17.00 - 18.00	16.8	16.5	16.2	15.5	15.9	16.0	16,3	15,8
18.00 - 19.00	16.6	16.5	16.0	15.5	15.5	15.8	15.7	15.4
19.00 - 20.00	15.5	15.5	14.8	14.2	14.3	14.7	14.5	14.0
20.00 - 21.00	13.9	14.2	14.0	13.5	12.2	13.3	13,2	13.2
21.00 - 22.00	12.9	13.1	12.6	13.1	11.5	12.3	12.9	12.9
22.00 - 23.00	12.1	12.4	13.0	13.1	10.2	11.3	12.0	12.4
23.00 - 24.00	11.9	12.1	12.7	12.8	10.0	11.2	11.8	12.2

Tab. 1: Cont.

Date 14.06.1979	Site II				Site III			
Hour (MEZ)	t_u °C	t_o °C	e_u mbar	e_o mbar	t_u °C	t_o °C	e_u mbar	e_o mbar
00.00 - 01.00	12.4	12.5	12.9	12.6	11.3	11.9	12.6	12.1
01.00 - 02.00	12.4	12.5	12.8	12.5	11.4	11.8	12.6	12.3
02.00 - 03.00	11.9	11.9	12.6	12.5	11.0	11.4	12.5	12.1
03.00 - 04.00	12.1	12.1	12.7	12.7	11.2	11.6	12.6	12.4
04.00 - 05.00	11.9	11.9	12.5	12.4	11.1	11.4	12.4	12.0
05.00 - 06.00	12.5	12.6	12.5	12.4	11.8	12.2	12.3	12.1
06.00 - 07.00	13.0	13.0	12.7	12.5	12.3	12.6	12.4	12.2
07.00 - 08.00	13.3	13.3	13.0	12.6	12.4	12.8	12.7	12.5
08.00 - 09.00	13.2	13.2	13.0	12.7	12.5	12.7	12.7	12.4
09.00 - 10.00	13.4	13.4	12.6	12.1	12.6	12.8	12.4	12.0
10.00 - 11.00	13.9	13.9	12.5	12.1	13.4	13.5	12.4	11.8
11.00 - 12.00	14.4	14.3	12.5	12.0	13.7	13.8	12.5	12.0
12.00 - 13.00	14.7	14.7	13.1	12.3	14.2	14.2	12.5	12.3
13.00 - 14.00	16.1	16.1	13.1	12.1	16.0	15.6	12.9	12.5
14.00 - 15.00	17.0	16.8	13.4	12.5	16.4	16.8	13.1	12.6
15.00 - 16.00	16.4	16.4	13.4	12.7	15.7	15.7	13.0	12.7
16.00 - 17.00	16.5	16.5	13.2	12.6	15.7	15.7	12.8	12.7
17.00 - 18.00	15.6	15.6	13.3	13.0	14.7	14.9	12.9	12.7
18.00 - 19.00	14.9	15.0	13.3	12.3	14.1	14.3	12.8	12.7
19.00 - 20.00	14.1	14.1	13.2	12.9	13.2	13.6	12.8	12-7
20.00 - 21.00	12.6	12.6	13.1	12.9	11.7	12.0	12.8	13.4
21.00 - 22.00	11.8	11.8	12.7	12.5	11.0	11.3	12.5	12.4
23.00 - 23.00	11.9	11.9	12.6	12.6	11.0	11.3	12.5	12.5
23.00 - 24.00	12.2	12.2	12.7	12.5	11.2	11.6	12.7	12.5

Tab. 1: Cont.

Date 15.05.1979	Site II				Site III			
Hour (MEZ)	t_u °C	t_o °C	e_u mbar	e_o mbar	t_u °C	t_o °C	e_u mbar	e_o mbar
00.00 - 01.00	11.8	12.0	12.5	12.3	11.1	11.5	12.5	12.1
01.00 - 02.00	11.8	11.9	13.8	12.5	11.1	11.4	12.6	12.3
02.00 - 03.00	11.8	11.8	13.8	12.4	11.0	11.4	12.5	12.1
03.00 - 04.00	11.7	11.9	12.2	12.2	11.0	11.5	12.2	12.0
04.00 - 05.00	11.6	11.8	12.1	11.9	10.9	11.3	11.9	11.7
05.00 - 06.00	11.0	11.1	11.8	11.6	10.2	10.6	11.7	11.5
06.00 - 07.00	10.7	10.8	12.0	11.8	10.1	10.1	11.8	11.7
07.00 - 08.00	10.1	10.0	11.6	11.3	9.4	9.5	11.4	11.2
08.00 - 09.00	9.7	9.5	11.0	10.7	9.3	9.2	11.0	10.6
09.00 - 10.00	11.5	11.0	11.6	11.0	11.4	10.8	11.7	11.3
10.00 - 11.00	12.9	12.4	11.9	10.9	12.4	12.1	11.5	11.2
11.00 - 12.00	14.2	13.5	11.8	10.7	13.5	13.2	12.1	11.5
12.00 - 13.00	14.7	14.0	12.1	10.9	14.1	13.6	11.8	11.3
13.00 - 14.00	14.0	13.7	12.3	11.4	13.4	13.3	12.1	11.6
14.00 - 15.00	14.2	13.7	12.1	11.3	13.6	13.3	11.9	11.5
15.00 - 16.00	12.2	12.1	11.9	11.6	11.7	11.6	11.9	11.4
16.00 - 17.00	11.6	11.2	12.1	11.8	10.8	10.8	12.0	11.5
17.00 - 18.00	12.5	12.3	12.3	11.8	12.0	11.8	12.3	12.1
18.00 - 19.00	13.2	13.0	12.3	12.1	12.5	12.5	12.7	12.1
19.00 - 20.00	13.1	13.0	12.9	12.6	12.3	12.5	13.1	12.6
20.00 - 21.00	12.3	12.4	13.0	12.7	11.4	12.1	13.2	12.2
21.00 - 22.00	10.4	10.8	12.2	12.3	9.7	10.3	10.8	11.6
22.00 - 23.00	10.2	10.5	12.1	12.1	9.4	9.8	11.2	11.5
23.00 - 24.00	10.4	10.5	12.4	12.5	9.8	9.9	11.8	11.9

Tab. 1: Cont.

Date 16.06.1979	Site II				Site III			
Hour (MEZ)	t_u °C	t_o °C	e_u mbar	e_o mbar	t_u °C	t_o °C	e_u mbar	e_o mbar
00.00 - 01.00	10.7	10.6	12.6	12.4	10.0	10.3	12.1	12.3
01.00 - 02.00	10.5	10.8	12.6	12.1	9.8	10.0	11.8	12.0
02.00 - 03.00	10.2	11.5	12.3	11.4	9.5	9.7	11.7	11.8
03.00 - 04.00	9.8	12.3	12.0	10.1	9.1	9.2	11.4	11.4
04.00 - 05.00	9.7	14.0	11.7	8.6	9.1	9.3	11.4	11.4
05.00 - 06.00	9.7	15.4	11.6	7.6	9.1	9.1	11.5	11.4
06.00 - 07.00	10.3	15.9	11.9	7.9	9.6	9.8	11.9	11.5
07.00 - 08.00	11.1	15.2	12.4	8.6	10.5	10.4	12.3	12.0
08.00 - 09.00	11.7	15.2	12.8	10.1	11.1	11.2	12.6	12.2
09.00 - 10.00	12.4	15.3	13.4	11.1	11.7	11.8	13.3	12.9
10.00 - 11.00	14.7	15.3	13.6	12.4	13.8	13.9	13.7	13.2
11.00 - 12.00	15.8	15.0	13.4	12.9	15.2	15.1	13.4	12.6
12.00 - 13.00	16.1	15.2	12.8	12.6	15.4	15.6	12.9	12.0
13.00 - 14.00	16.4	16.5	12.8	12.0	15.8	16.1	12.6	11.7
14.00 - 15.00	15.0	15.2	12.8	12.2	14.3	14.7	12.4	11.7
15.00 - 16.00	15.1	15.3	13.3	12.5	14.2	14.8	12.6	12.0
16.00 - 17.00	15.2	15.3	13.7	12.9	14.4	14.8	13.3	12.5
17.00 - 18.00	14.7	15.0	13.4	12.6	14.1	14.5	12.8	12.2
18.00 - 19.00	14.4	14.8	12.6	11.9	13.6	14.3	12.3	11.5
19.00 - 20.00	13.9	14.3	11.9	11.0	12.9	13.8	11.4	10.5
20.00 - 21.00	13.5	13.9	12.5	11.9	12.7	13.3	12.2	11.4
21.00 - 22.00	13.2	13.5	11.4	11.0	12.4	12.8	10.9	11.0
22.00 - 23.00	11.6	11.9	11.3	11.0	10.8	11.3	10.7	10.6
23.00 - 24.00	10.1	10.3	11.1	10.9	9.3	9.6	10.7	10.6

Tab. 1: Cont.

Date 17.06.1979	Site II				Site III			
Hour (MEZ)	t_u °C	t_o °C	e_u mbar	e_o mbar	t_u °C	t_o °C	e_u mbar	e_o mbar
00.00 - 01.00	8.9	9.1	10.6	10.7	8.2	8.5	10.2	10.5
01.00 - 02.00	8.3	8.5	10.5	10.5	7.5	7.9	10.2	10.3
02.00 - 03.00	7.4	7.6	9.9	10.1	6.5	6.9	9.3	9.7
03.00 - 04.00	7.7	7.8	10.1	10.2	6.7	7.0	9.5	9.8
04.00 - 05.00	8.4	8.4	10.7	10.6	7.7	7.8	10.2	10.4
05.00 - 06.00	9.2	9.2	11.2	11.0	8.5	8.7	10.8	10.9
06.00 - 07.00	9.9	9.8	11.6	11.3	9.3	9.3	11.4	11.4
07.00 - 08.00	11.8	11.5	12.0	11.6	11.4	11.2	11.9	11.6
08.00 - 09.00	13.4	13.0	11.7	11.2	13.0	12.8	11.6	11.2
09.00 - 10.00	13.9	13.5	11.9	11.4	13.7	13.5	11.8	11.4
10.00 - 11.00	14.4	14.1	11.8	11.2	14.0	13.8	11.7	11.3
11.00 - 12.00	14.0	13.8	12.1	11.5	13.6	13.4	11.7	11.4
12.00 - 13.00	14.4	14.3	12.2	11.5	13.8	13.7	12.0	11.6
13.00 - 14.00	14.2	14.1	12.4	11.9	13.5	13.7	12.1	11.5
14.00 - 15.00	14.2	14.1	12.4	11.9	13.6	13.7	12.3	11.7
15.00 - 16.00	15.2	15.1	12.4	11.9	14.3	14.5	12.3	11.6
16.00 - 17.00	15.1	15.0	12.1	11.6	14.6	14.7	11.8	11.2
17.00 - 18.00	14.4	14.2	11.4	11.8	13.7	14.0	11.1	10.6
18.00 - 19.00	13.2	13.1	10.7	10.2	12.5	12.8	10.4	9.8
19.00 - 20.00	11.9	11.9	10.1	9.9	11.1	11.4	9.9	9.4
20.00 - 21.00	11.2	11.3	10.0	9.7	10.5	10.8	9.7	9.4
21.00 - 22.00	10.9	10.9	10.1	9.9	10.1	10.5	9.9	9.8
22.00 - 23.00	10.5	10.6	10.1	9.8	9.6	10.0	9.8	9.8
23.00 - 24.00	10.5	10.6	10.4	10.2	9.7	10.1	10.0	10.0

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Tab. 1: Cont.

Date 16.06.1979	Site II				Site III			
Hour (MEZ)	t_u °C	t_o °C	e_u mbar	e_o mbar	t_u °C	t_o °C	e_u mbar	e_o mbar
00.00 - 01.00	10.6	10.6	10.7	10.4	9.7	10.1	10.3	10.1
01.00 - 02.00	10.6	10.7	10.8	10.6	9.8	10.1	10.7	10.6
02.00 - 03.00	10.7	10.9	11.1	10.9	10.1	10.4	10.8	10.8
03.00 - 04.00	10.9	10.8	11.3	11.1	10.1	10.4	11.1	11.1
04.00 - 05.00	10.5	10.5	11.6	11.5	10.0	10.2	11.3	11.3
05.00 - 06.00	10.6	10.6	11.8	11.6	10.1	10.2	11.6	11.3
06.00 - 07.00	11.0	10.9	12.0	11.9	10.5	10.7	11.8	11.6
07.00 - 08.00	11.4	11.3	12.0	11.9	10.9	11.1	12.1	11.6
08.00 - 09.00	12.0	11.8	12.0	11.9	11.5	11.7	11.9	11.6
09.00 - 10.00	12.6	12.4	12.6	12.3	12.3	12.4	12.5	12.1
10.00 - 11.00	13.5	13.3	13.3	13.1	13.1	13.1	13.2	12.8
11.00 - 12.00	14.0	14.0	13.5	13.3	13.8	13.8	13.6	13.2
12.00 - 13.00	14.7	14.6	13.9	13.7	14.2	14.3	13.8	13.5
13.00 - 14.00	15.6	15.4	14.5	13.9	15.2	15.1	14.2	13.8
14.00 - 15.00	16.0	15.9	14.4	14.0	15.4	15.4	14.2	13.8
15.00 - 16.00	16.3	16.3	14.4	14.1	15.8	16.0	14.4	13.8
16.00 - 17.00	16.5	16.4	14.6	14.2	15.9	15.9	14.5	14.1
17.00 - 18.00	16.8	16.7	14.7	14.3	16.3	16.3	14.7	14.2
18.00 - 19.00	16.5	16.5	14.7	14.4	15.6	15.9	14.4	14.5
19.00 - 20.00	15.5	15.7	14.7	14.4	14.7	15.1	14.3	14.3
20.00 - 21.00	16.6	16.0	14.0	14.0	12.8	13.3	13.7	13.7
21.00 - 22.00	12.3	12.6	13.6	13.7	11.3	11.8	13.0	13.1
22.00 - 23.00	11.4	11.8	13.1	13.1	10.6	11.1	12.4	12.5
23.00 - 24.00	10.5	10.7	12.4	12.5	9.7	10.2	11.6	11.9

Tab. 1: Cont.

Date 19.06.1979	Site II				Site III			
Hour (MEZ)	t_u °C	t_o °C	e_u mbar	e_o mbar	t_u °C	t_o °C	e_u mbar	e_o mbar
00.00 - 01.00	11.6	11.6	13.1	13.1	11.1	11.2	12.9	12.7
01.00 - 02.00	11.5	11.4	13.1	13.2	11.0	11.1	13.0	12.6
02.00 - 03.00	11.2	11.1	13.0	13.0	10.8	10.9	12.9	12.6
03.00 - 04.00	11.1	11.1	13.0	12.9	10.7	10.8	12.9	12.5
04.00 - 05.00	11.1	11.1	13.0	13.1	10.7	10.8	12.9	12.6
05.00 - 06.00	11.2	11.1	13.0	13.1	10.8	10.8	13.0	12.7
06.00 - 07.00	11.8	11.2	13.2	13.2	10.9	11.0	12.9	12.7
07.00 - 08.00	11.4	11.2	13.0	13.1	10.9	10.9	12.9	12.6
08.00 - 09.00	11.7	11.4	13.2	13.0	11.3	11.1	12.8	12.6
09.00 - 10.00	12.3	11.8	13.4	13.1	12.0	11.7	13.3	12.9
10.00 - 11.00	13.1	12.5	13.9	13.4	12.8	12.8	13.6	13.1
11.00 - 12.00	13.8	13.2	14.4	13.6	13.4	13.3	13.8	13.4
12.00 - 13.00	14.5	14.0	14.6	14.0	14.1	13.7	14.4	13.9
13.00 - 14.00	15.6	14.9	15.1	14.5	15.5	15.0	14.9	14.3
14.00 - 15.00	17.5	17.0	16.4	14.8	17.8	16.9	16.1	15.5
15.00 - 16.00	18.6	18.2	16.2	15.0	18.6	18.6	15.9	15.1
16.00 - 17.00	18.9	18.4	16.0	14.9	18.8	18.3	15.7	15.2
17.00 - 18.00	19.0	18.7	15.8	14.7	18.6	18.4	15.5	15.0
18.00 - 19.00	17.7	17.7	15.8	15.1	17.0	17.3	15.5	14.8
19.00 - 20.00	16.2	16.3	16.8	15.5	15.1	15.9	15.6	15.3
20.00 - 21.00	14.5	14.6	15.4	15.3	13.6	14.1	14.9	14.8
21.00 - 22.00	12.8	13.2	14.0	14.2	12.0	12.7	13.3	13.7
22.00 - 23.00	11.3	11.7	12.9	13.1	10.3	11.1	11.9	12.3
23.00 - 24.00	10.3	10.5	12.1	12.4	9.0	9.7	11.2	11.7

Tab. 2 a: Daily means of heat budget and daily sums of actual evapotranspiration
Ruthe June 9 to 21 Site II (Sugar beet).

Date	$\bar{R}_n$	$\bar{G}$	$\overline{l \cdot E}$	$\bar{H}$	ΣE
09.06.	134.9	-4.5	-110.3	-20.1	3.87
10.06.	166.8	-6.3	-124.4	-36.1	4.36
11.06.	122.1	-9.3	- 47.7	-65.1	1.68
12.06.	155.4	-9.1	- 85.7	-60.6	3.02
13.06.	104.1	-1.4	- 77.6	-25.1	2.73
14.06.	57.8	9.8	- 66.5	- 1.1	2.33
15.06.	69.7	1.8	- 52.1	-19.4	1.82
16.06.	58.9	0.2	- 50.2	- 8.9	1.76
17.06.	87.1	4.6	- 77.5	-14.2	2.71
18.06.	54.9	-0.3	- 48.2	- 6.4	1.68
19.06.	111.4	-3.7	- 78.1	-29.6	2.74
20.06.	181.7	-18.1	-128.9	-34.7	4.53
21.06.	188.9	-13.2	-170.2	- 5.5	6.01

$\bar{R}_n$ = net radiation ($W \cdot m^{-2}$)

$\bar{G}$ = soil heat flux ($W \cdot m^{-2}$)

$\overline{l \cdot E}$ = latent heat flux ($W \cdot m^{-2}$)

$\bar{H}$ = sensible heat flux ($W \cdot m^{-2}$)

ΣE = evapotranspiration ($kg \cdot m^{-2} \cdot d^{-1}$) daily sums

Tab. 2 b: Daily means of heat budget and evapotranspiration
Ruthe June 9 to 21 Site III (Barley)

Date	$\bar{R}_n$	$\bar{G}$	$\overline{L \cdot E}$	$\bar{H}$	Σ E
09.06.	63.8	0.4	- 60.9	- 3.3	2.14
10.06.	123.3	0.7	- 91.2	-26.5	3.19
11.06.	100.5	-5.6	- 90.5	- 4.4	3.19
12.06.	(122.3)	-6.1	-100.5	-15.7	3.53
13.06.	(82.7)	1.6	- 76.6	- 7.7	2.69
14.06.	(48.3)	5.5	- 50.6	- 3.2	1.77
15.06.	(58.6)	(4.3)	- 44.2	-18.7	1.54
16.06.	45.8	4.3	- 56.2	6.1	1.97
17.06.	74.8	1.9	- 69.9	- 6.8	2.57
18.06.	45.9	5.7	- 55.5	3.9	1.94
19.06.	85.6	1.0	- 61.6	-25.0	2.19
20.06.	137.6	-4.1	-108.0	-25.5	3.80
21.06.	155.6	-6.9	-133.1	-15.6	4.55

(explanation of symbols see tab. 2 a)

( ) = interpolated values

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Tab. 2c: Daily sums of potential evaporation
Ruthe and Völkenrode, June 09 - 21, 1979
EPH = after Haude Formula
EPC = after ceramic evaporimeter
ELY = actual evapotranspiration wheat (lysimeter)

Date June 1979	Ruthe EPH mm	Ruthe EPC mm	Völkenrode EPH mm	Völkenrode EPC mm	Völkenrode ELY mm
09.	2.7	2.6	2.2	3.0	4.0
10.	2.1	2.2	2.0	2.6	2.9
11.	3.5	2.0	3.0	2.9	3.8
12.	3.2	3.3	2.3	3.6	4.7
13.	1.7	1.3	1.8	2.1	3.2
14.	1.9	2.3	2.1	3.2	4.6
15.	1.3	1.4	1.2	1.5	2.7
16.	1.5	1.6	1.1	1.9	1.9
17.	1.2	2.7	1.1	3.5	3.4
18.	1.2	2.6	0.9	1.5	1.5
19.	1.3	1.7	1.5	1.8	3.0
20.	3.2	3.0	3.0	3.0	4.9
21.	5.5	5.2	5.6	6.7	6.7

Tab. 3: Hourly values of air temperatures t, water vapour pressures e, net radiation Rn, soil heat flux G, latent enthalpy lE and sensible heat flux H, during flight measurement program.
Ruthe, June 20 - 22, 1979, Site II (sugar beet)

Indices: u = lower level (50 cm)
o = upper level (200 cm)

20.06.1979

Hour	tu °C	to °C	eu mbar	eo mbar	Rn W/m²	G W/m²	lE W/m²	H W/m²
00.00 - 01.00	10.1	10.2	11.9	12.1	-29.0	28.7	0.2	-0.1
01.00 - 02.00	9.4	9.5	11.5	11.8	-29.1	32.1	-2.8	-0.2
02.00 - 03.00	8.9	9.0	11.2	11.3	-27.6	32.2	-3.0	-1.6
03.00 - 04.00	8.4	8.7	10.8	11.1	-22.4	31.3	-5.9	-3.0
04.00 - 05.00	8.3	8.3	10.7	10.9	-0.6	25.4	-25.5	0.7
05.00 - 06.00	10.0	9.9	12.2	12.2	68.0	6.0	-26.0	-48.0
06.00 - 07.00	12.1	11.7	13.5	13.4	161.6	-20.8	-61.9	-78.9
07.00 - 08.00	13.8	13.5	14.5	14.5	282.6	-39.9	-144.3	-98.4
08.00 - 09.00	15.8	15.5	15.6	15.1	388.1	-91.5	-208.8	-87.8
09.00 - 10.00	18.6	17.7	16.6	15.7	473.0	-107.8	-220.2	-145.0
10.00 - 11.00	19.5	19.2	17.2	16.1	374.9	-69.5	-258.6	-46.8
11.00 - 12.00	20.4	20.1	16.5	15.3	440.3	-52.7	-331.3	-56.3
12.00 - 13.00	21.0	20.6	16.2	14.8	305.9	-57.2	-211.0	-37.7
13.00 - 14.00	2 .2	21.5	16.2	15.0	600.8	-81.0	-376.8	-143.0
14.00 - 15.00	22.1	21.7	16.3	15.1	371.4	-73.6	-240.3	-57.5
15.00 - 16.00	22.6	22.1	16.5	15.8	460.3	-79.2	-267.9	-113.2
16.00 - 17.00	22.6	22.5	17.1	15.5	360.5	-50.0	-292.3	-18.2
17.00 - 18.00	22.4	22.4	16.9	15.8	244.4	-2.5	-239.0	-2.9
18.00 - 19.00	21.8	12.9	17.1	16.3	117.9	8.8	-140.2	13.5
19.00 - 20.00	20.4	21.0	17.9	16.9	8.9	13.0	-37.7	15.8
20.00 - 21.00	18.2	19.9	17.5	16.4	-45.2	26.1	-12.2	31.3
21.00 - 22.00	15.7	17.7	16.5	16.5	-50.4	28.8	0.2	21.4
22.00 - 23.00	14.9	15.7	15.9	16.1	-48.3	28.4	5.2	14.7
23.00 - 24.00	13.5	13.8	14.9	15.2	-45.4	28.6	8.8	8.0

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Tab. 3: Cont.

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Hour (MEZ)	tu °C	to °C	eu mbar	eo mbar	Rn W/m²	G W/m²	lE W/m²	H W/m²
00.00 - 01.00	13.2	13.2	14.5	15.0	-33.9	28.1	5.5	0.3
01.00 - 02.00	12.5	12.8	14.1	14.7	-25.4	28.2	-2.2	-0.6
02.00 - 03.00	11.9	12.3	13.8	14.1	-20.2	27.7	-3.7	-3.8
03.00 - 04.00	11.4	12.3	13.3	14.2	-15.0	27.0	-7.5	-4.5
04.00 - 05.00	11.3	11.8	13.1	13.7	-3.5	23.6	-13.4	-6.7
05.00 - 06.00	13.1	13.1	14.8	14.7	51.1	9.9	-36.2	-24.8
06.00 - 07.00	15.5	16.0	16.4	15.9	150.0	-14.2	-131.2	-4.6
07.00 - 08.00	17.8	17.8	17.7	17.0	252.0	-31.1	-205.8	-15.1
08.00 - 09.00	20.2	20.1	18.2	17.3	347.9	-76.4	-250.3	-21.2
09.00 - 10.00	22.0	21.8	19.0	17.9	428.1	-43.8	-360.6	-23.7
10.00 - 11.00	24.0	23.6	19.0	17.5	494.1	-47.7	-376.0	-70.4
11.00 - 12.00	25.0	24.5	17.6	16.1	482.8	-62.3	-335.8	-84.7
12.00 - 13.00	25.3	25.2	17.0	15.4	509.4	-57.0	-435.7	-16.7
13.00 - 14.00	26.4	26.0	15.2	13.4	573.8	-86.9	-433.1	-53.8
14.00 - 15.00	26.1	25.9	16.5	14.6	465.1	-69.7	-361.7	-33.7
15.00 - 16.00	26.2	25.8	15.6	14.1	412.9	-48.5	-317.7	-46.7
16.00 - 17.00	25.8	25.7	16.2	14.9	324.6	-41.3	-270.2	-13.1
17.00 - 18.00	25.1	25.2	15.4	14.7	222.7	-8.8	-244.2	30.3
18.00 - 19.00	24.0	24.4	15.5	14.7	102.4	8.9	-165.9	54.6
19.00 - 20.00	21.9	22.7	16.2	15.4	4.3	15.6	-70.2	50.3
20.00 - 21.00	19.7	20.8	16.9	16.2	-44.6	23.5	-13.6	34.7
21.00 - 22.00	16.9	18.3	16.8	16.0	-48.5	26.3	-14.0	36.2
22.00 - 23.00	15.7	17.1	16.1	15.6	-48.5	26.8	-28.5	50.2
23.00 - 24.00	15.9	17.0	15.7	15.4	-49.1	26.5	-12.8	35.4

22.06.1979

Hour (MEZ)	tu °C	to °C	eu mbar	eo mbar	Rn W/m²	G W/m²	lE W/m²	H W/m²
00.00 - 01.00	14.1	15.2	15.3	15.0	-49.1	28.0	-12.5	33.6
01.00 - 02.00	13.6	14.3	14.4	14.4	-48.3	27.3	0.1	20.9
02.00 - 03.00	13.3	14.1	14.5	14.3	-36.6	23.2	-10.3	23.7
03.00 - 04.00	19.3	14.6	14.7	14.3	-21.3	18.7	8.3	-5.7
04.00 - 05.00	15.2	15.4	15.5	15.2	-6.4	9.7	-20.2	10.9
05.00 - 06.00	15.3	15.3	16.3	16.0	-5.0	8.4	-3.4	0.0
06.00 - 07.00	15.8	15.9	16.8	16.8	-2.0	8.0	-12.8	6.8

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Tab. 4: Hourly values of air temperatures t, water vapour pressure e, net radiation Rn, soil heat flux G, latent enthalpy lE and sensible heat flux H, during flight measurement program
Ruthe, June 20 - 22, 1979, Site III (barley)
Indices: u = lower level (50 cm)
o = upper level (200 cm)

20.06.1979

Hour (MEZ)	tu °C	to °C	eu mbar	eo mbar	Rn W/m^2	G W/m^2	lE W/m^2	H W/m^2
00.00 - 01.00	8.9	9.6	10.8	11.5	-14.7	18.5	-2.2	-1.6
01.00 - 02.00	8.3	9.0	10.7	11.3	-16.2	18.5	-1.3	-1.0
02.00 - 03.00	7.5	8.5	10.1	10.8	-15.1	19.6	-2.3	-2.2
03.00 - 04.00	6.9	7.9	9.6	10.3	-14.9	21.5	-3.4	-3.2
04.00 - 05.00	7.0	7.7	9.8	10.3	-4.7	18.7	-7.3	-6.6
05.00 - 06.00	9.3	9.5	11.6	11.8	43.2	9.7	-30.9	-22.0
06.00 - 07.00	11.5	11.4	13.4	13.1	108.2	-0.4	-94.6	-13.2
07.00 - 08.00	13.2	13.0	14.7	14.1	199.0	-0.5	-155.9	-38.1
08.00 - 09.00	15.8	15.3	15.5	15.0	329.1	-10.7	-202.7	-115.7
09.00 - 10.00	17.9	17.4	16.2	15.7	378.4	-18.7	-216.9	-142.8
10.00 - 11.00	18.8	18.6	15.9	15.2	255.1	-21.7	-199.5	-33.9
11.00 - 12.00	20.1	19.9	15.8	15.0	364.1	-28.7	-285.9	-49.5
12.00 - 13.00	20.5	20.3	15.7	14.5	302.9	-31.4	-243.0	-28.5
13.00 - 14.00	21.4	21.0	15.5	14.6	325.4	-34.7	-231.3	-59.4
14.00 - 15.00	21.7	21.4	16.0	15.0	394.5	-36.6	-284.2	-73.7
15.00 - 16.00	22.2	21.8	16.1	15.3	331.5	-36.2	-208.2	-87.1
16.00 - 17.00	22.1	21.8	16.4	15.5	233.0	-23.6	-177.3	-32.1
17.00 - 18.00	21.4	21.5	16.4	14.5	135.0	-15.9	-135.2	16.1
18.00 - 19.00	20.4	20.9	16.6	15.8	71.2	-6.7	-103.1	38.6
19.00 - 20.00	18.6	19.9	17.0	16.0	1.8	1.2	-20.7	17.7
20.00 - 21.00	16.1	18.6	15.8	15.9	-27.2	11.8	0.8	14.6
21.00 - 22.00	13.7	15.6	14.5	15.7	-27.0	17.2	3.8	6.0
22.00 - 23.00	12.5	15.4	13.2	14.9	-25.1	17.4	3.6	4.1
23.00 - 24.00	11.7	12.9	13.3	14.8	-26.2	16.8	6.1	3.3

Tab. 4: Cont.

21.06.1979

Hour (MEZ)	tu °C	to °C	eu mbar	eo mbar	Rn W/m²	G W/m²	lE W/m²	H W/m²
00.00 - 01.00	10.9	12.6	12.8	14.3	-20.3	17.9	1.4	1.0
01.00 - 02.00	10.0	12.4	12.0	14.0	-17.0	18.7	-1.0	-0.7
02.00 - 03.00	9.7	11.9	11.8	13.7	-15.6	19.1	-2.0	-1.5
03.00 - 04.00	9.2	11.6	11.4	13.4	-15.1	19.1	-2.2	-1.8
04.00 - 05.00	9.9	11.3	11.9	13.2	-3.2	16.7	-7.6	-5.9
05.00 - 06.00	12.1	12.2	13.9	14.1	36.9	8.3	-29.0	-16.2
06.00 - 07.00	15.0	14.8	16.0	16.0	112.3	-1.1	-9.2	-102.0
07.00 - 08.00	17.7	17.4	17.2	17.0	216.0	-7.1	-132.6	-76.3
08.00 - 09.00	20.4	20.0	18.0	17.6	309.8	-14.5	-184.4	-110.9
09.00 - 10.00	22.1	21.7	18.7	18.1	377.1	-22.3	-243.9	-110.9
10.00 - 11.00	23.8	23.3	12.3	17.1	419.2	-30.3	-312.3	-76.6
11.00 - 12.00	24.5	24.1	16.8	15.9	369.2	-34.2	-255.1	-79.9
12.00 - 13.00	25.5	24.9	15.9	14.7	489.1	-45.5	-339.8	-103.8
13.00 - 14.00	26.2	25.6	15.5	14.1	461.1	-43.8	-395.7	-109.2
14.00 - 15.00	25.4	25.3	15.8	14.5	394.2	-37.2	-340.6	-16.4
15.00 - 16.00	25.2	25.3	14.9	14.2	312.7	-37.6	-290.2	15.1
16.00 - 17.00	24.6	24.8	15.3	14.6	237.7	-24.0	-263.2	49.5
17.00 - 18.00	23.6	24.2	15.3	14.5	147.1	-13.4	-227.5	93.8
18.00 - 19.00	22.1	23.0	15.5	14.9	60.3	-5.1	-138.0	90.0
19.00 - 20.00	20.1	21.3	15.7	15.3	-3.1	1.8	-1.1	2.4
20.00 - 21.00	17.6	19.3	15.7	15.2	-32.1	8.4	-16.6	40.3
21.00 - 22.00	15.5	17.8	15.4	15.3	-33.9	13.7	0.0	20.2
22.00 - 23.00	14.2	16.4	14.8	14.7	-33.6	15.1	-1.3	19.3
23.00 - 24.00	13.9	15.8	14.4	14.2	-34.7	12.6	-3.5	25.6

22.06.1979

Hour (MEZ)	tu °C	to °C	eu mbar	eo mbar	Rn W/m²	G W/m²	lE W/m²	H W/m²
00.00 - 01.00	12.2	14.5	13.8	14.6	-35.3	16.0	7.0	12.3
01.00 - 02.00	12.0	13.7	13.5	13.8	-34.3	16.2	4.2	13.9
02.00 - 03.00	11.6	13.2	13.1	13.5	-26.2	14.4	3.3	8.5
03.00 - 04.00	13.2	14.0	13.8	13.6	-16.2	9.1	-3.3	10.4
04.00 - 05.00	14.2	14.6	14.8	14.5	-3.7	4.6	-6.4	5.5
05.00 - 06.00	14.3	14.7	15.6	15.1	-10.9	3.2	16.4	-8.7
06.00 - 07.00	14.9	15.2	16.0	16.2	-8.6	2.0	3.5	3.1
07.00 - 08.00	15.1	15.3	16.5	16.5	8.1	0.7	-2.7	-6.[illegible]
08.00 - 09.00	15.1	15.3	16.7	16.2	33.[illegible]	-0.6	-4[illegible].4	[illegible]

Tab. 5: Hourly values of air temperature t, wet bulb temperature t' (both 100 cm above soil), global radiation Rg, short wave reflection Rr, net radiation Rn, soil heat flux G, latent enthalpy lE and sensible heat flux H during flight measurement program.
Völkenrode, June 20 - 22, 1979, winter wheat

20.06.1979

Hour (MEZ)	t °C	t' °C	Rg W/m²	Rr W/m²	Rn W/m²	G W/m²	lE W/m²	H W/m²
00.00 - 01.00	12.1	11.7	0.0	0.3	-42.7	13.4	-6.9	36.2
01.00 - 02.00	11.2	10.7	0.0	0.4	-35.7	15.9	-6.9	26.7
02.00 - 03.00	11.3	11.1	1.0	0.9	-17.6	12.7	-6.9	11.8
03.00 - 04.00	11.0	10.4	1.3	0.9	-19.5	14.5	-13.7	18.7
04.00 - 05.00	10.2	10.0	20.1	4.5	- 5.9	14.6	-6.9	-1.8
05.00 - 06.00	11.4	11.1	89.8	20.9	33.6	12.5	-48.0	1.9
06.00 - 07.00	13.7	12.9	192.8	42.0	97.9	-3.3	-89.2	-5.4
07.00 - 08.00	16.2	14.0	355.5	72.6	190.7	-14.5	-123.5	-52.7
08.00 - 09.00	18.0	14.9	517.2	98.7	294.9	-25.0	-219.5	-50.4
09.00 - 10.00	18.9	15.7	586.2	110.1	363.1	-29.1	-267.5	-66.5
10.00 - 11.00	19.2	16.0	554.4	97.6	341.8	-28.9	-260.7	-52.2
11.00 - 12.00	19.7	16.1	451.9	81.6	295.1	-25.3	-247.0	-22.8
12.00 - 13.00	20.4	16.6	471.9	84.2	305.3	-24.9	-281.3	0.9
13.00 - 14.00	-	-	-	-	-	-	-	-
14.00 - 15.00	-	-	-	-	-	-	-	-
15.00 - 16.00	22.3	17.5	609.4	110.5	368.4	-22.2	-329.3	-16.9
16.00 - 17.00	22.3	17.6	473.5	90.5	277.8	-16.1	-260.7	-6.0
17.00 - 18.00	21.9	17.6	353.2	73.3	196.4	-13.0	-198.9	15.5
18.00 - 19.00	21.1	17.4	196.8	43.7	78.9	-5.2	-96.0	22.3
19.00 - 20.00	19.3	17.0	75.4	17.3	-22.2	2.3	-27.4	47.3
20.00 - 21.00	16.3	15.4	10.2	1.4	-43.4	11.3	-13.7	45.8
21.00 - 22.00	14.3	13.8	1.2	0.4	-45.5	15.7	-6.9	36.7
22.00 - 23.00	13.4	13.0	0.9	0.7	-44.1	16.5	-6.9	34.5
23.00 - 24.00	12.3	12.1	0.8	0.3	-41.2	17.2	-13.7	37.7

Tab. 5: Cont.

21.06.1979

Hour (MEZ)	t °C	t' °C	Rg W/m^2	Rr W/m^2	Rn W/m^2	G W/m^2	lE W/m^2	H W/m^2
00.00 - 01.00	11.9	11.7	1.1	0.6	-35.0	17.2	-6.9	-24.7
01.00 - 02.00	11.3	11.1	1.1	0.5	-22.2	17.2	0.0	-5.0
02.00 - 03.00	11.0	10.9	0.8	0.8	-14.7	17.0	0.0	-2.2
03.00 - 04.00	10.4	10.3	1.7	1.4	-12.5	17.5	0.0	-5.0
04.00 - 05.00	10.7	10.6	24.2	8.3	1.7	15.0	-6.9	-9.8
05.00 - 06.00	13.8	13.5	113.7	32.7	54.5	3.9	-41.2	-27.0
06.00 - 07.00	17.1	15.6	250.2	61.5	139.8	-7.8	-150.7	-18.9
07.00 - 08.00	19.4	16.5	394.8	83.1	211.6	-18.9	-185.2	-7.6
08.00 - 09.00	21.2	17.3	539.8	100.6	302.2	-28.6	-267.5	-6.1
09.00 - 10.00	22.9	18.1	657.5	115.9	377.8	-33.9	-336.1	-7.8
10.00 - 11.00	24.2	18.4	752.5	126.7	443.7	-40.0	-432.2	28.5
11.00 - 12.00	24.8	17.6	830.1	134.8	495.1	-48.9	-473.3	27.1
12.00 - 13.00	24.6	16.6	748.1	118.9	437.3	-34.8	-432.2	29.5
13.00 - 14.00	25.0	17.1	752.5	122.8	449.8	-31.7	-466.5	48.4
14.00 - 15.00	25.3	17.7	734.2	132.5	462.0	-27.0	-514.5	79.5
15.00 - 16.00	25.3	17.4	708.9	122.6	397.3	-20.3	-452.8	75.8
16.00 - 17.00	24.5	17.1	424.0	83.1	245.5	-12.2	-315.6	82.3
17.00 - 18.00	23.6	16.4	249.1	49.1	118.7	-4.2	-198.9	84.7
18.00 - 19.00	23.5	16.3	195.7	46.3	75.6	-1.4	-164.6	90.4
19.00 - 20.00	22.4	16.0	78.7	19.8	-7.0	2.5	- 88.8 1)	93.3
20.00 - 21.00	20.5	15.5	11.1	2.7	-47.0	7.8	- 20.5 1)	59.7
21.00 - 22.00	18.2	15.1	0.3	0.5	-49.8	12.0	-13.7 1)	51.5
22.00 - 23.00	17.0	14.6	0.0	0.8	-48.9	13.3	-27.4	63.0
23.00 - 24.00	16.4	14.1	0.0	0.8	-46.4	12.8	-34.3	67.9

22.06.1979

Hour (MEZ)	t °C	t' °C	Rg W/m^2	Rr W/m^2	Rn W/m^2	G W/m^2	lE W/m^2	H W/m^2
00.00 - 01.00	16.5	13.9	0.7	0.7	-40.9	11.0	-48.0	77.9
01.00 - 02.00	16.3	13.5	0.1	0.9	-45.3	10.3	-96.0	131.0
02.00 - 03.00	16.3	13.3	0.0	0.9	-49.3	11.1	-48.0	86.2
03.00 - 04.00	15.9	12.9	0.8	1.2	-52.0	10.9	-54.9	96.0
04.00 - 05.00	15.8	12.9	29.3	9.2	-27.9	9.3	-34.3	52.9
05.00 - 06.00	15.7	13.6	121.5	32.2	28.2	2.4	-75.5	44.0
06.00 - 07.00	16.3	14.4	224.9	50.8	108.8	-6.5	-150.3	[illegible]

1) Interpolated from lysimeter data

Tab. 6 : Hourly values of air temperature t, wet bulb temperature t' (both 200 cm above soil), global radiation Rg, short wave reflection Rr, net radiation Rn, soil heat flux G, latent enthalpy lE and sensible heat flux H during flight measurement program
Völkenrode, June 20 - 22, 1979, grass

20.06.1979

Hour (MEZ)	t °C	t' °C	Rg W/m^2	Rr W/m^2	Rn W/m^2	G W/m^2	lE W/m^2	H W/m^2
00.00 - 01.00	12.3	11.9	0.0	-2.2	-27.4	8.2	-14.4	33.6
01.00 - 02.00	11.6	11.3	0.0	-1.9	-25.0	0.7	-10.3	25.6
02.00 - 03.00	11.7	11.4	1.0	-1.2	-15.4	8.5	-6.7	13.6
03.00 - 04.00	11.2	11.1	1.3	-1.3	-21.6	8.7	-6.7	19.6
04.00 - 05.00	10.9	10.9	20.1	2.4	-9.4	9.4	-6.7	6.7
05.00 - 06.00	11.4	11.2	89.8	19.1	21.5	5.3	-6.7	-20.1
06.00 - 07.00	13.5	12.5	192.8	42.3	89.5	-2.7	-27.4	-59.4
07.00 - 08.00	15.5	13.4	355.5	75.0	209.7	-12.9	-116.6	-80.2
08.00 - 09.00	17.0	14.0	517.2	103.2	331.3	-23.1	-205.8	-102.4
09.00 - 10.00	17.9	14.6	586.2	112.7	406.3	-30.9	-247.0	-128.4
10.00 - 11.00	18.7	15.1	554.4	104.0	398.6	-32.0	-247.0	-119.5
11.00 - 12.00	19.2	15.1	451.9	85.8	341.0	-27.8	-205.8	-107.4
12.00 - 13.00	19.9	15.4	471.9	90.2	353.1	-27.6	-233.2	-90.3
13.00 - 14.00	-	-	-	-	-	-	-	-
14.00 - 15.00	-	-	-	-	-	-	-	-
15.00 - 16.00	21.7	16.5	609.4	122.7	449.8	-24.4	-308.7	-116.7
16.00 - 17.00	21.8	16.4	473.5	99.1	333.7	-19.9	-233.2	-80.6
17.00 - 18.00	21.9	16.7	353.2	79.3	228.9	-13.1	-164.6	-51.2
18.00 - 19.00	21.1	16.9	196.8	46.2	102.2	-4.9	-89.2	-8.1
19.00 - 20.00	19.6	16.9	75.4	16.9	14.4	1.0	-34.3	18.9
20.00 - 21.00	17.9	15.8	10.2	-1.0	-21.1	6.3	-6.7	21.5
21.00 - 22.00	16.6	14.8	1.2	-2.3	-6.4	9.5	-6.7	5.5
22.00 - 23.00	15.8	14.3	0.9	-1.7	-4.7	10.2	-6.7	1.2
23.00 - 24.00	14.6	13.9	0.8	-1.8	-5.0	10.6	-6.7	1.1

Tab. 6 : Cont.

21.06.1979

Hour (MEZ)	t °C	t' °C	Rg W/m²	Rr W/m²	Rn W/m²	G W/m²	lE W/m²	H W/m²
00.00 - 01.00	14.2	13.6	1.1	-1.6	-21.7	10.8	6.9	3.9
01.00 - 02.00	13.4	13.2	1.1	-1.6	-18.1	10.9	6.9	0.2
02.00 - 03.00	13.1	13.0	0.8	-1.5	-13.3	10.8	0.0	2.5
03.00 - 04.00	12.7	12.7	1.7	-1.2	-9.5	10.9	0.0	-1.4
04.00 - 05.00	12.1	12.2	24.2	5.2	1.9	9.8	-6.9	-4.7
05.00 - 06.00	13.6	13.4	113.7	29.4	32.2	2.7	-27.4	-7.4
06.00 - 07.00	16.9	15.1	250.2	60.6	111.2	-8.2	-96.0	-6.8
07.00 - 08.00	19.0	15.7	394.8	86.8	224.3	-17.6	-157.8	-48.8
08.00 - 09.00	20.8	16.3	539.9	109.0	343.3	-27.6	-253.8	-61.6
09.00 - 10.00	22.4	16.9	675.5	126.3	451.8	-35.3	-329.3	-86.8
10.00 - 11.00	24.0	17.2	752.5	139.9	536.8	-40.0	-418.5	-77.9
11.00 - 12.00	24.7	16.3	880.1	152.2	608.8	-42.6	-487.1	-78.6
12.00 - 13.00	24.8	15.1	748.1	137.1	559.6	-38.8	-459.6	-60.7
13.00 - 14.00	25.1	15.6	752.5	143.1	569.3	-35.4	-466.1	-66.9
14.00 - 15.00	25.5	16.5	734.2	150.0	549.9	-28.5	-439.0	-81.9
15.00 - 16.00	25.6	16.4	708.9	135.3	474.8	-22.5	-370.4	-81.4
16.00 - 17.00	25.0	16.2	424.0	89.9	293.0	-14.6	-247.0	-31.3
17.00 - 18.00	24.4	15.8	249.1	51.8	151.2	-6.8	-150.9	13.5
18.00 - 19.00	24.3	15.9	195.7	48.9	100.4	-1.1	-130.3	31.1
19.00 - 20.00	23.3	15.9	78.7	19.8	16.7	+2.1	-54.9	36.2
20.00 - 21.00	22.0	15.7	11.1	1.0	-24.7	+5.1	-13.7	33.2
21.00 - 22.00	20.2	15.7	0.3	-1.6	31.1	+7.1	0.0	-38.2
22.00 - 23.00	19.1	15.1	0.0	-1.1	33.1	+7.7	0.0	-40.0
23.00 - 24.00	18.4	14.5	0.0	-1.1	-30.0	+7.9	0.0	22.1

22.06.1979

Hour (MEZ)	t °C	t' °C	Rg W/m²	Rr W/m²	Rn W/m²	G W/m²	lE W/m²	H W/m²
00.00 - 01.00	17.7	14.1	0.7	-1.0	-25.4	7.5	0.0	17.9
01.00 - 02.00	17.3	13.7	0.1	-1.0	-28.8	7.2	0.0	21.6
02.00 - 03.00	17.2	13.4	0.0	-1.0	-31.8	7.7	6.9	[illegible]
03.00 - 04.00	16.8	13.1	0.8	-0.6	-34.0	8.0	0.0	[illegible]
04.00 - 05.00	16.9	13.1	29.3	6.8	-12.7	7.0	0.0	5.7
05.00 - 06.00	16.5	13.4	121.5	29.3	38.2	17.3	41.2	-96.7
06.00 - 07.00	17.0	14.1	224.9	49.5	126.4	-53.3	68.6	[illegible]

Tab. 7: Hourly values of actual evapotranspiration (ETA) and potential evaporation of ceramic disc 2 m (EP) of four different sites during flight measurement program Ruthe and Völkenrode, June 20 - 22, 1979

20.06.1979	Ruthe			Völkenrode		
	site II sugar beet	site III barley	ceramic disc	wheat	grass	ceramic disc
Hour (MEZ)	ETA mm	ETA mm	EP mm	ETA mm	ETA mm	EP mm
00.00 - 01.00	0.00	0.00	0.00	0.01	0.02	0.00
01.00 - 02.00	0.00	0.00	0.00	0.01	0.01	0.00
02.00 - 03.00	0.00	0.00	0.00	0.01	0.01	0.00
03.00 - 04.00	0.00	0.00	0.00	0.02	0.01	0.00
04.00 - 05.00	0.04	0.01	0.00	0.01	0.01	0.00
05.00 - 06.00	0.04	0.04	0.00	0.07	0.02	0.00
06.00 - 07.00	0.09	0.14	0.00	0.13	0.04	0.00
07.00 - 08.00	0.21	0.23	0.05	0.18	0.17	0.04
08.00 - 09.00	0.31	0.30	0.16	0.32	0.30	0.16
09.00 - 10.00	0.32	0.32	0.24	0.39	0.36	0.18
10.00 - 11.00	0.38	0.29	0.33	0.38	0.36	0.23
11.00 - 12.00	0.49	0.42	0.45	0.36	0.30	0.26
12.00 - 13.00	0.31	0.36	0.51	0.41	0.34	0.27
13.00 - 14.00	0.55	0.34	0.53	-	-	0.28
14.00 - 15.00	0.35	0.42	0.51	-	-	0.28
15.00 - 16.00	0.39	0.31	0.50	0.48	0.45	0.29
16.00 - 17.00	0.43	0.26	0.51	0.38	0.34	0.29
17.00 - 18.00	0.35	0.20	0.48	0.29	0.24	0.26
18.00 - 19.00	0.31	0.15	0.37	0.14	0.13	0.20
19.00 - 20.00	0.06	0.03	0.23	0.04	0.05	0.10
20.00 - 21.00	0.02	0.00	0.14	0.02	0.01	0.07
21.00 - 22.00	0.00	0.01	0.07	0.01	0.01	0.02
22.00 - 23.00	0.00	0.00	0.04	0.01	0.01	0.00
23.00 - 24.00	0.00	0.01	0.02	0.02	0.01	0.00

Tab.7 : Cont.

21.06.1979	Ruthe			Völkenrode		
	site II sugar beet	site III barley	ceramic disc	wheat	grass	ceramic disc
Hour (MEZ)	ETA mm	ETA mm	EP mm	ETA mm	ETA mm	EP mm
00.00 - 01.00	0.01	0.00	0.00	0.01	0.01	0.00
01.00 - 02.00	0.00	0.00	0.00	0.00	0.01	0.00
02.00 - 03.00	0.01	0.00	0.00	0.00	0.00	0.00
03.00 - 04.00	0.01	0.00	0.00	0.00	0.00	0.00
04.00 - 05.00	0.02	0.01	0.00	0.01	0.01	0.00
05.00 - 06.00	0.05	0.04	0.00	0.06	0.04	0.00
06.00 - 07.00	0.19	0.01	0.01	0.22	0.14	0.00
07.00 - 08.00	0.30	0.19	0.10	0.27	0.23	0.16
08.00 - 09.00	0.37	0.27	0.23	0.39	0.37	0.20
09.00 - 10.00	0.53	0.36	0.35	0.49	0.48	0.30
10.00 - 11.00	0.55	0.46	0.48	0.63	0.61	0.38
11.00 - 12.00	0.49	0.38	0.62	0.69	0.71	0.50
12.00 - 13.00	0.64	0.50	0.78	0.63	0.67	0.55
13.00 - 14.00	0.64	0.58	0.91	0.68	0.68	0.60
14.00 - 15.00	0.53	0.50	0.98	0.75	0.64	0.60
15.00 - 16.00	0.47	0.43	0.96	0.66	0.54	0.50
16.00 - 17.00	0.40	0.39	0.90	0.46	0.36	0.50
17.00 - 18.00	0.36	0.33	0.80	0.28	0.23	0.42
18.00 - 19.00	0.24	0.05	0.59	0.24	0.19	0.38
19.00 - 20.00	0.10	0.00	0.37	0.13[1]	0.08	0.29
20.00 - 21.00	0.02	0.02	0.24	0.03[1]	0.02	0.17
21.00 - 22.00	0.02	0.00	0.15	0.02[1]	0.00	0.12
22.00 - 23.00	0.04	0.00	0.11	0.04	0.00	0.10
23.00 - 24.00	0.02	0.00	0.02	0.02[1]	0.00	0.08

1) Lysimeter data

22.06.1979						
00.00 - 01.00	0.02	0.01	0.03	0.07	0.00	0.10
01.00 - 02.00	0.00	0.01	0.03	0.10	0.02	0.10
02.00 - 03.00	0.02	0.00	0.02	0.07	0.01	0.10
03.00 - 04.00	0.01	0.00	0.02	0.08	0.00	0.10
04.00 - 05.00	0.03	0.01	0.02	0.05	0.00	0.10
05.00 - 06.00	0.01	0.02	0.03	0.11	0.06	0.10
06.00 - 07.00	0.02	0.01	0.03	0.19	0.11	0.12

Tab. 8 : Hourly mean values of surface temperatures [1)]
site II (sugar beet)
Ruthe, June 20 - 22, 1979

Hour (MEZ)	20.06.1979 to °C	21.05.1979 to °C	22.06.1979 to °C
00 - 01	-	10.2	12.1
01 - 02	-	9.6	11.4
02 - 03	-	9.0	11.8
03 - 04	-	8.8	12.5
04 - 05	-	9.1	13.4
05 - 06	-	11.3	13.6
06 - 07	-	14.6	13.8
07 - 08	-	17.6	-
08 - 09	-	20.3	-
09 - 10	20.4	22.9	-
10 - 11	20.2	24.8	-
11 - 12	20.4	26.6	-
12 - 13	19.9	25.8	-
13 - 14	21.4	26.5	-
14 - 15	21.0	23.2	-
15 - 16	21.0	22.4	-
16 - 17	21.2	22.1	-
17 - 18	19.9	20.9	-
18 - 19	18.2	19.4	-
19 - 20	16.8	17.4	-
20 - 21	14.6	15.2	-
21 - 22	13.0	14.0	-
22 - 23	11.7	13.3	-
23 - 24	10.6	13.1	-

1) Infrared thermometer Heimann KT 24.

Tab 9 : Hourly mean values of surface temperatures of site III (barley) Ruthe, June 20 - 22, 1979 [1]

Hour (MEZ)	20.06.1979 to °C	21.06.1979 to °C	22.06.1979 to °C
00 - 01	-	9.7	11.8
01 - 02	-	9.1	11.3
02 - 03	-	8.7	11.2
03 - 04	-	8.4	12.7
04 - 05	-	8.9	13.9
05 - 06	-	12.8	14.5
06 - 07	-	17.4	15.0
07 - 08	-	21.1	-
08 - 09	-	22.5	-
09 - 10	22.0	24.0	-
10 - 11	20.3	24.6	-
11 - 12	21.8	25.3	-
12 - 13	22.4	23.8	-
13 - 14	20.9	23.9	-
14 - 15	21.5	23.2	-
15 - 16	21.7	22.7	-
16 - 17	21.0	21.9	-
17 - 18	20.0	20.8	-
18 - 19	18.7	19.4	-
19 - 20	16.8	17.6	-
20 - 21	13.5	15.8	-
21 - 22	11.8	14.2	-
22 - 23	11.2	12.9	-
23 - 24	10.5	13.1	-

1) Infrared thermometer Heimann KT 24.

Tab.10: Phenometrical data of site II (sugar beet) and site III (barley)
Ruthe June 1979

I Sugar beet (measurements taken at June 22)

Density of the canopy:	6 plants/m^2
Mean leaf area:	2062 cm^2/plant
standard deviation:	±650 cm^2/plant
Leaf area index LAI:	1.24

II Barley (measurements taken at June 19, 20 Plants)

Canopy height:	110 cm
Mean number of stalks per plant:	4,4
Mean number of ears per plant:	3,4
Mean leaf area:	11,2 cm
Number of plant rows per meter	8
Mean number of plants per m^2:	148
Mean number of stalks per m^2:	651
Mean number of ears per m^2:	459
Mean leaf area per stalk:	39,9 cm^2
Mean number of leaves per plant:	1,69
Mean portion of dry leaves:	29 %
Mean portion of dry leaf area:	15 %
Mean leaf area per plant:	173 cm^2
standard deviation:	±96 cm^2
Leaf area index LAI:	2,6

Tab.11: Internal resistances r_{St} of sugar beets (site II) Ruthe June 20 and 21. Resistances r_{St} in $s \cdot cm^{-1}$

	Time	sun leaves	middle leaves	shaded leaves	mean
20.06.1979	10.00	1.22	1.56	1.72	1.50
	11.00	1.47	1.84	5.20	2.84
	12.00	1.33	1.64	4.99	2.65
	15.00	1.[illegible]3	2.36	4.07	2.76
	17.00	2.30	2.17	4.45	2.97
21.06.1979	09.30	0.72	0.76	5.44	2.31
	10.30	0.97	1.72	5.04	2.58
	11.30	1.56	2.09	5.93	3.19
	12.30	1.99	2.23	4.33	2.85
	13.30	2.96	3.85	8.41	5.07
	15.30	2.42	--	--	--
	17.30	3.62	3.52	3.13	3.42

Tab. 12.: Internal resistances r_{St} of barley leaves (site III) in different heights
Ruthe June 20 and 21. Resistances in $s \cdot cm^{-1}$

	Time	90 - 110 cm	20 - 90 cm	0 - 20 cm	mean
20.06.1979	10.30	2.06	1.75	5.45	3.09
	11.30	0.90	1.29	2.91	1.70
	14.30	2.36	2.73	8.93	4.67
	15.30	1.99	2.62	12.09	5.57
21.06.1979	10.00	1.10			
	11.00	2.94			
	12.00	1.50			
	13.00	3.30			
	14.00	1.88			
	16.00	2.65			
	18.00	3.04			

Tab. 13: Thermal conductivity λ, thermal diffusivity k^2, and heat capacity ϱc of soils at different soil moistures for a mean dry bulk density of 1,5 g/cm^3, regarding a quartzite fraction of 98%. Ruthe 1979

site	soil moisture Vol %	λ W $cm^{-1}K^{-1}$	k^2 $10^{-3}cm^2s^{-1}$	ϱc W s $K^{-1}cm^{-3}$
II	12.5	0.011	7.97	1.38
I	13.8	0.010	7.19	1.39
II	16.0	0.025	17.60	1.42
II	19.7	0.031	21.38	1.45
III	21.9	0.029	19.73	1.47
II	23.3	0.025	16.78	1.49
II	24.3	0.023	15.33	1.50
II	28.5	0.015	9.74	1.54
III	28.5	0.020	12.87	1.54

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13. Agrometeorological Measurements on Field Nr. 4

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Introduction and objectives

During the Joint Measuring Campaign 1979 near Ruthe soil water and agrometeorological measurements were taken at seven different locations, scattered over the entire test site. This contribution reports about the agrometeorological measurements taken at Field Nr. 4, in the middle of an 7 ha large wheat (Triticum aestivum L.) field. The location of Field Nr. 4 is indicated in Fig. 5 of chapter 2. More details about the field can be seen in Fig. 1. The field is about 475 m long and 150 m wide. Also shown is the location in the field where the soil, plant and micrometeorological data were collected. The wheat field was surrounded by another wheat field in the north, by barley in the west, by sugar beets in the south and by small fields with different crops in the east (wheat, barley, rye and sugar beets). Objective of the measurements taken on Field Nr. 4 was to evaluate the heat and the water budget during selected periods of the Campaign. To accomplish this, a variety of parameters was measured. Among them were wet and dry temperatures in two heights above the crop, the radiation balance, the wind way and the precipitation. Soil temperatures and crop temperatures were also determined. Furthermore the root distribution, the hydraulic properties of the soil, leaf water potential, crop height, vapor diffusion resistances, particle size distribution of the soil, gravimetric soil water content and soil suction distribution were determined at one or more occasions. From these measurements an estimation of the heat and the water budget of the site can be made. Also the crop temperature can be simulated. The simulated crop temperature

can be compared with the temperature as measured on the ground, from the airplane or from the HCMM-satellite. In this way the usefulness of remote sensing for water and energy budget evaluations can be investigated. The measurements taken at the test plot in the wheat field will now be described in some detail.

Methods and materials

A weather station, which location is indicated in Fig. 1, was installed in the middle of the field. Measured on the masts were wet and dry temperatures, the radiation balance and the wind way and wind direction.
The wet and dry temperatures were measured in 1 and 2 m above the soil surface. They were recorded with psychrometers of the Frankenberger type (Product of the Th. Friedrich Company in Hamburg, Pt-100 sensors, 12-V direct current aspiration motor, type 3010). The temperatures were recorded on a 6-channel, 6-color point recorder (Product of the Ph. Schenk Company, Vienna, Type Srk 63). The 4 temperatures were recorded in the measuring rang 0-50°C one after the other. The recording speed for 1 data point per channel is 20 seconds. This means that for each temperature there are 30 recordings per hour. Since the conveyance velocity of the recording paper is 20 mm/h the distance between data points for each channel is about 0.7 mm. The scale of the recording paper is nonlinear and the processing of the recorded data has to be carried out manually. Fig. 2 gives an impression about the data chart. Shown are psychrometer data pertaining to June 21, 1979 (the day of the flight experiment). A calibration of the temperature sensors and the recording unit was performed with a calibration bath before and after the Campaign (Lauda-Thermostat, Typ k4R Electronic). The radiation balance was measured in 2 m height with a net radiation sensor (Product of the Middleton Company, Port Melbourne, Type CN1). The hemisphere was flushed with nitrogen. The sensitivity of the sensor is indicated as 0.0429 mV/W m^{-2}. The recording was done with an apparatus similar to the one used for the air

temperature readings (6-channel, 6 color-point recorder, Schenk Company, Vienna, type STD 64). Also here the data processing afterwards was carried out manually. The measuring range of the apparatus is -5 to +50 mV.
Both for the psychrometers and for the radiation sensor the power supply was provided with a 12 V - 36 Ah car battery. The batteries had to be recharged daily. The recording units were installed in a wheather unit about 25 m away from the sensors. Also measured were wind speed and wind direction. A mechanical wind speed and wind direction sensor as developed by Wölfle and as produced by the Lambrecht Company in Göttingen was used. The measurements were made in 2 m height. Also here the recording stripe needed to be processed manually. Finally also the precipitation was recorded. A self-recording rain gauge was installed 1 m above the soil surface. An attempt was made to measure also the soil temperatures in 2, 5, 10, 20 and 40 cm depth. However, it turned out, that the recording unit was unreliable, and that the registered values cannot be trusted. Crop temperatures were measured in two different ways;
a) by bringing a sensing unit in direct contact with plant leaves, b) with a radiation thermometer. For the first method an YSI Tele-thermometer (Simpson Electric Co., Chicago) was used. Heights in which plant temperatures were measured were about 15, 30 and 60 cm (the heights differed slightly on different days). Also the air temperature above the canopy in about 125 cm height was recorded. Since the sensors were insufficiently shielded the value of the data is somewhat uncertain. For the second method a Heimann radiation (KT 24) thermometer was used (courtesy of Dr. Gossmann from the Geography Institute of the University of Freibourg, West Germany). The thermometer is a product of the Heimann Co., Physikalisch-Technische Werkstätten, 6200 Wiesbaden-Dotzheim. The measurements were made in irregular intervals. Each time measurements were made from about 150 cm height at 30, 20 or 10 different locations close to the weather mast. (For example on June 18 at 9.30, 12.00, 12.45, 15.05, 16.5 17.25, 20.05, 20.35 and 21.00 o'clock).

The plant height at Field Nr. 4 was measured at 3 occasions: on June 11, June 18 and on June 21. Measurements were also here

made in two different ways: a) by measuring a large number (about 100) separate plants out of a row (by cutting the plants), b) by determination of an apparent crop height in the vicinity of a measuring stick, that was standing up in the field (at 10 different locations).
A number of other parameters was measured on Field Nr. 4, e.g. leaf potential, leaf vapor diffusion resistance, soil suction, soil water content, soil moisture characteristic, hydraulic conductivity, biomass, leaf area etc. These measurements will be treated elsewhere.

Results

For illustration purposes some results will be presented here. Figure 3 shows the course of the dry temperature in 1 meter height on June 21. Also shown in Fig. 3 is the wind speed on June 21 in 2 m height and the radiation balance.
Table 1 shows some of the crop temperature readings taken on June 21, either with the ISY-telethermometer (left part) or with the Heiman radiation thermometer (from 150 cm height above the soil surface). It can be seen that within the crop, especially at midday temperature gradients exist and that in the upper layers (57 and 28 cm) the temperature is considerably higher than in the air (126 cm) above the canopy.
Table 2 shows readings concerning the crop height. The left part of the Table shows readings from individual plants. Out of one row all plants were cut with a rasor blade over a distance of about 1 m. Of each plant the height was then determined. The right half of the Table shows apparent crop heights determined by eye-balling in 10 different locations in the field. As average crop height for June 21 the value 75 cm was taken. On June 11 a height of 62 cm was determined in this way.

Table 3 shows the occurrence of precipitation at Field Nr. 4 and also at Field Nr. 2 during the Campaign. The total amount of precipitation on Field 4 between June 10 and June 22 was 18.8 mm.

Table 4 finally gives an impression about the days at which readings pertaining to this chapter, were collected. The tabulized data can be obtained from the JRC in Ispra or directly from the authors.

Conclusions

A large number of soil, plant and atmospheric parameters was measured at Field Nr. 4 during the Joint Measuring Campaign. These parameters were either components of the water and heat budget of the field (like precipitation or net radiation) or quantities needed to derive such components that cannot be measured directly (like wet and dry temperatures above the crop, soil suction values below the root zone). The collected data can be used in models dealing with soil-plant-atmospheric interrelations, that simulate crop temperature. The simulated crop temperature can be compared with measured temperature data (like from an air plane or a satellite). In case calculated and measured crop temperatures agree closely, evidence has been collected that supports the use of remote sensing for heat and water budget studies in agricultural areas.

LEGEND TO FIGURES AND TABLES OF CHAPTER 13

Fig. 1	Location of measuring devices on Field Nr. 4 and other information concerning the wheat crop.
Fig. 2	A section of the data chart with psychrometer data of June 21.
Fig. 3	The course of the air temperature in 1 m height, the net radiation and the wind velocity of Field Nr. 4 on June 21.
Table 1.	Crop temperatures, as recorded with an ISY-telethermometer (left part of the Table) and with a radiation thermometer (right part), on Field Nr. 4 on June 21.
Table 2	Crop heights, as recorded from single plants (left part) and from the entire stand on June 21 at Field Nr. 4.
Table 3	The occurrence of precipitation on Field Nr. 4 between June 7 and June 22.
Table 4	An overview about the data collected on Field Nr. 4 during the Joint Measuring Campaign.

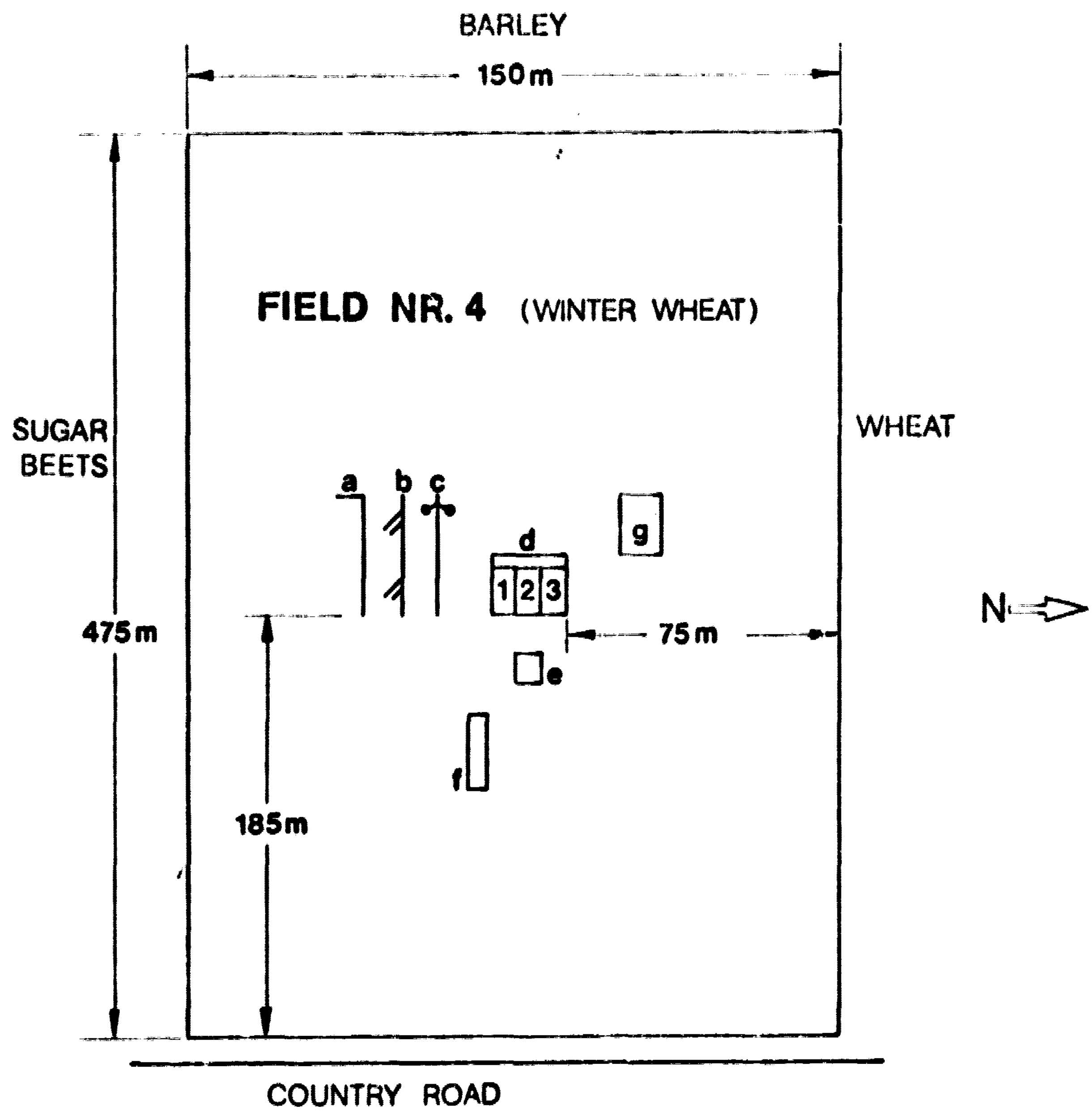
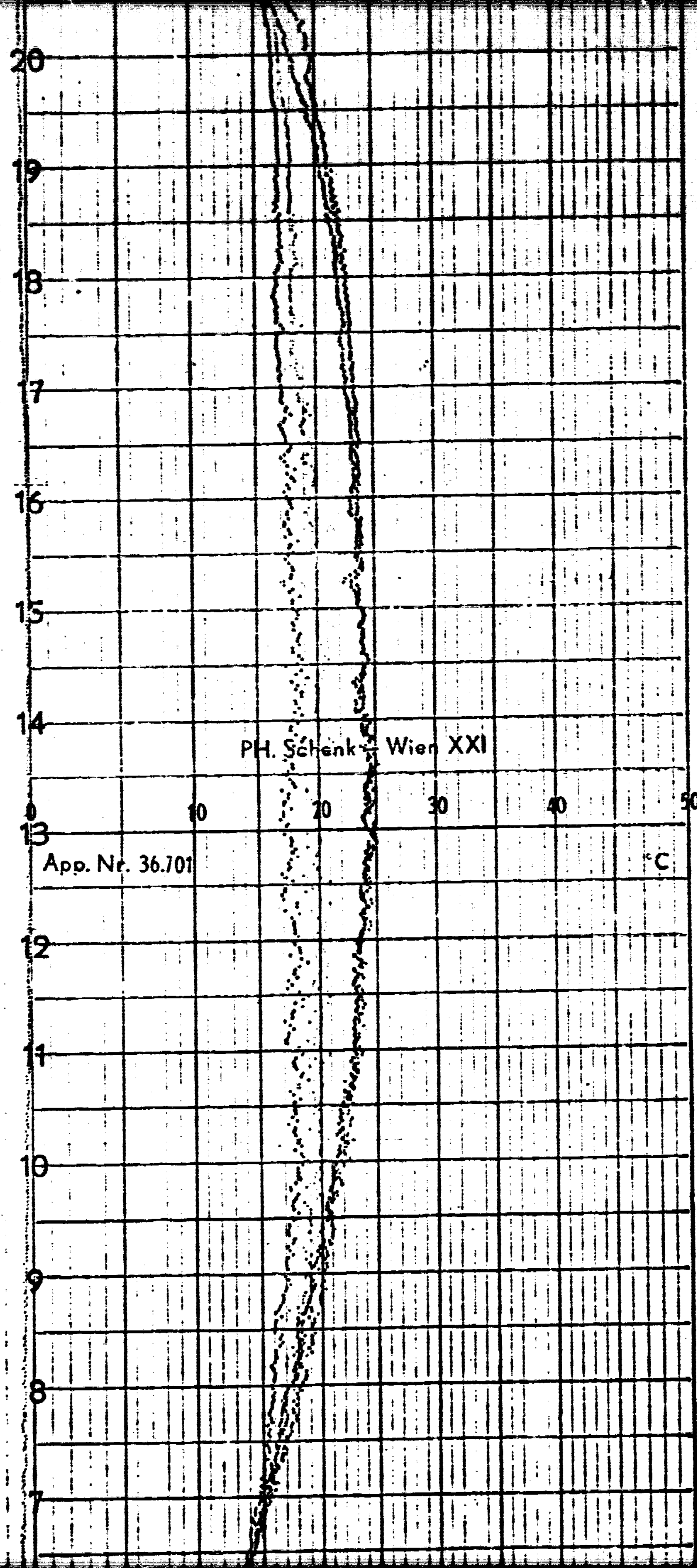

BARLEY
150m
FIELD NR. 4 (WINTER WHEAT)
SUGAR BEETS
WHEAT
a
b
c
d
1
2
3
g
475m
75m
N
e
f
185m
COUNTRY ROAD

Fig.13.1



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C-3

Fig. 13.2

AIR TEMPERATURE, WIND VELOCITY AND NET RADIATION ON PLOT NR. 4 (WINTERWHEAT) ON JUNE 21, 1979

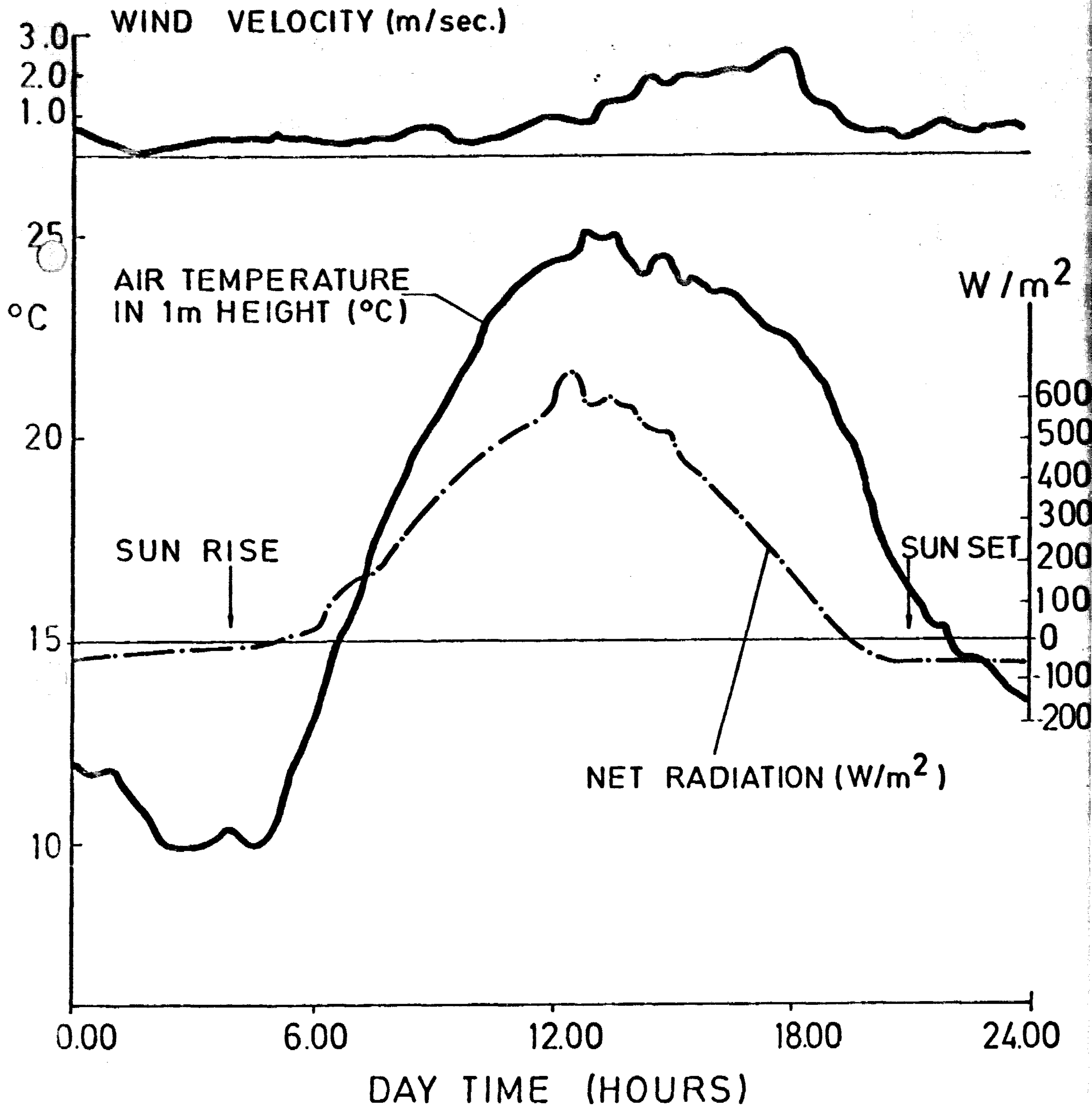


Fig.13.3

	HEIGHT (cm)				TIME (hour)			
TIME	57	28	14	126	12.15	13.00	13.35	14.30
11.40	29.0	30.2	25.5	27.0	23.9	24.0	23.5	21.9
12.20	28.5	30.3	26.0	26.2	24.0	23.9	23.5	21.0
13.05	29.9	30.5	27.3	27.1	24.2	24.3	23.5	21.2
13.35	28.9	27.0	26.5	26.4	23.9	24.1	23.7	21.5
14.05	26.5	24.1	25.1	25.5	25.1	26.2	23.6	21.7
15.45	25.4	23.2	24.6	25.8	25.9	24.0	24.2	22.2
18.33	21.9	20.5	20.8	22.5	25.5	25.2	24.1	22.0
19.20	20.0	19.0	19.5	21.2	24.7	23.8	26.1	22.5
21.10	15.2	15.2	16.0	17.2	26.2	23.9	26.4	22.3
22.45	12.1	12.0	13.0	13.2	24.3	23.9	24.0	22.0
00.45	12.1	12.0	13.0	13.2				
01.50	11.5	12.0	12.5	12.9				

Table 13.1

SINGLE PLANTS (cm)				STAND (cm)	
74.2	78.9	68.0	79.5		
64.5	82.5	74.5	79.8		
64.1	74.5	82.6	70.4	83	76
70.5	68.0	58.4	71.2	80	75
63.0	68.1	76.4	78.6	74	78
76.0	76.9	83.7	72.3	75	80
76.6	75.2	39.8	75.2	78	78
78.0	63.8	60.0	72.4	68	78
64.1	71.1	71.4	83.4	74	75
75.4	79.7	76.0	75.9	70	77
81.0		60.1		75	76
71.5		81.0		81	75
62.1		50.6			
53.5		64.6			
66.2		75.7			

Table 13.2

PRECIPITATION DATA FROM THE PERIOD JUNE 10 - JUNE 22

day (June)	Field nr. 2 (mm)	Field nr. 4 (mm)
10 th	—	—
11	—	—
12	—	—
13	10.7	9.6
14	0.8	0.7
15	6.1	4.0
16	0.2	0.2
17	—	—
18	—	—
19	—	—
20	—	—
21	—	—
22	4.4*	4.3*
TOTAL	22.2	18.8

*Between 0.00 and 8.00 A.M.

Table 13.3

parameter measured	DAY IN JUNE 7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
air temperatures										X	X	X	X	X	X	X
wind										X	X	X	X	X	X	X
radiation										X	X	X	X	X	X	X
precipitation		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
soil suction	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
soil water content		X		X		X		X		X		X		X		X
leaf water potential		X						X				X	X	X	X	
leaf temperature												X	X	X	X	
crop temperature												X	X	X	X	
diffusion resistance												X	X	X	X	
plant height					X							X			X	
leaf area index								X								
root distribution									X							

Table 13.4

14. Agrometeorological Measurements on Fields Nr. 5, 6 and 7

K. Blyth, S. Jagger, B. Callender and M. Elkington

U K Joint Contribution

Introduction and Objectives

During the period September 1977 to April 1979, ground measurements were taken in the UK at sites near Grendon Underwood, Newbury and Leeds to coincide with HCMM satellite overpasses. In addition, an aircraft measurement campaign was undertaken in September 1977 to collect low level thermal infra red and visible data over the Grendon Underwood and Newbury test areas. These data have been used as input to the Tergra and Tell-us models which simulate heat transport around the soil/atmosphere interface in order to estimate soil moisture and daily evapotranspiration, and work to date indicates that the models perform adequately for homogeneous short grassland and bare earth situations. However, no ground information existed for taller crops or mixed crop situations, as in the past sufficient instrumentation and manpower could not be assembled to adequately cover these cases. The Joint Measuring Campaign provided a rare opportunity to gather coincident ground data for several surface types by bringing together the resources of many European Institutes and Universities. One of the main objectives was, therefore, to assemble data sets for crops of different heights, in order to test the capabilities of the Tergra and Tell-us models, and also of a simpler model, in more complex heat transfer situations, but under identical climatological situations.

The UK HCMM test sites used to date have, of necessity, been single crop, homogeneous areas of at least 3 satellite pixels in area to ensure that measured ground temperatures and reflectances

were representative of at least one pixel value. Such large homogeneous areas are atypical of UK mixed farming practice, where normally a single satellite pixel would represent an integral of values from a number of crop types. The simultaneous collection of ground data from several crops during the Joint Campaign enables statistical 'scaling up' simulations to be undertaken to relate measured soil moisture and evapotranspiration values to estimated values from the Tell-us and Tergra models as predicted from a selection of theoretical pixel sizes. Optimum pixel sizes can then be calculated for different agricultural situations.

In addition, the provision of aircraft data from three altitudes, together with ground and possibly coincident satellite data provides an opportunity to determine atmospheric degradation of measured radiative temperatures and to examine possible techniques for correcting such effects.

METHODS & MATERIALS

The Institute of Hydrology, the University of Reading and the University of Leeds jointly instrumented three test sites during the JMC which were situated to the west of the experimental area. The three plots, as shown on Fig. 1, carried crops of sugar beet (2.1 ha) barley (5.4 ha) and wheat (1.5 ha), all on the same very fine and homogeneous loess soils. Both the barley and wheat crops were well developed with canopies giving complete ground cover and of mean height 1.2 m and 0.6 m respectively. The sugar beet was however, poorly advanced with the vegetation canopy providing only about 25%

cover of the bare earth, although this developed during the campaign, and at the time of the aircraft overpasses, gave 45% cover.

Similar instrumentation and soil sampling regimes were used for each of the three plots. A single representative site was chosen towards the centre of each plot where all of the required meteorological and soil variables were measured, the central location being chosen to minimize edge effects and to maximise the wind fetch over each crop. Where possible, the instrumentation of the three sites (marked V, K and D on Fig. 1) was automatically recording, in order to free the limited ground team for the collection of replicate manual measurements at some of the minor sites. Automatic instrumentation was generally left to operate continuously after its installation in order to ensure the collection of at least 24 hours of data prior to the aircraft overpass.

During the analysis of linescan data, it is essential that the location of ground measurements (especially of those which are known to be spatially variable such as surface temperature and soil moisture) be known. In order to achieve this, ground markers comprising white polythene sheets measuring approx 3 m x 2 m were placed at known distances and bearings from each of the main instrument sites. In addition, the plot boundaries and all of the instrument sites shown on Fig. 1 were located by theodolite survey.

INSTRUMENTATION

A comprehensive listing of instrumentation and measurements taken at all sites (A-ZZ) for each of the three fields appears as Table 1, but a short description of the instrument set-up for each field follows.

<u>Sugar beet field</u>

Instrumentation in the sugar beet field was largely intended to provide data suitable for measurement of the components of the energy balance at the crop/atmosphere interface and for input to the Tergra and Tell-us soil moisture models.

Thus, radiation balance was determined by a four sensor set-up. The short-wave components, incident and reflected, were measured by Kipp and Zonen CM5 Solarimeters (0.3-2.5 μm) which consequently provided information on the short-wave albedo. The total radiation balance was monitored by Schenk pyrradiometers sensing both downward and upward going total radiation (<80μm). Hence from these data it was possible to quantify individual short and long wavelength streams. These instruments were mounted at a height of 2.0 m.

Information on ground heat flux was determined at three sites. At the main meteorological site, two sets of soil thermometers were installed. These consisted of two sets of thermistors, one set continuously monitored at depths of -0.05, -0.10, -0.25 and -0.50 m and a second manually-read set placed at -0.02, -0.05, -0.10, -0.20, -0.30 and -0.50 m depths. In addition a Middleton Instruments soil heat flux plate was set at -0.075 m at the main meteorological site. In order to investigate the variation of soil temperature over the field, further manually-read YSI soil thermistor probes (Identical to that at site V) were located at two other points in the field, viz sites X and W. (Figure 1). All manually-read soil thermistors were read at 3-hourly intervals by attaching a Keithley Digital Multimeter.

To monitor sensible and latent heat fluxes, two different techniques were employed at different sites in the field. At the main site (V), two Schenk ventilated platinum resistance psychrometers and two Vector Instruments cup anemometers were installed at 0.50 m and 1.50 m heights above the crop. Such instruments gave data on the Bowen ratio and thus information on the evaporative flux, providing an independent check on the predictions of the numerical soil moisture models. In addition a 'Fluxatron' eddy correlation system was installed at site W, providing a direct measurement of sensible heat flux. Vertical wind speed was measured using a vertically mounted Gill propeller anemometer (R.M.Young Co.) set at 4.7 m above ground level, whilst ambient air temperature near the anemometer was measured using a fast-response bead thermistor (ITT Components group, model P25). Output from these sensors was converted into a single voltage which was proportional to instantaneous heat flux by the 'Fluxatron' circuitry and was subsequently integrated to produce 15 minute values. Total available energy was initially estimated from G/Rn correlations derived from detailed micrometeorological studies in the UK of cereal and other crops, but these values will be checked against measured soil heat flux at site V. By assuming that the fluxes of sensible and latent heat obey a diffusion equation and that the eddy diffusivities of heat and water vapour are equal, then in steady state conditions, the ratio of the two (the Bowen ratio) can be determined.

Infra red measurements on the beet site were obtained with a Barnes Instatherm infra red thermometer with 2.8^{o} field of view. This was mounted on a 4 m tower to provide a realistic surface spot size

of $\sim$ 14 cm. The instrument, sensitive to wavelengths > 8μm, was mounted in an insulated box to minimise environmental errors and was provided with a thermistor attached to its case to monitor the instrument body temperature and so provide a calibration check for the correction of observations.

All automatically-recording instrumentation was interfaced to a Microdata 12 channel logger and data recorded on cassette tape excepting the Vector Instruments wind measuring equipment, which employed a Rustrak 2-channel chart recorder. Recording intervals were varied between 10 and 2 minutes.

This data collection set-up was complemented by soil physical measurements carried out by the Universities of Hanover and Goettingen. These largely comprised of mercury tensiometers set at a series of depths and read manually every day during the campaign. Just prior to, during and after the aircraft flight, however, the frequency of observations was increased to 8 per day.

Since, at the opening of the campaign, the vegetation canopy on the beet field was not well-developed and increased from 25% to 45% during the experiment, it will be interesting to determine just which soil moisture models most accurately describe the behaviour of the crop and if this changed during the campaign. As an aid to such investigations, vegetation cover was monitored by taking vertical photographs from a height of 2 m using false colour infra red film. Areas of soil and vegetation were determined from these photographs using a Cambridge Instruments Quantimet Image Analysis System.

Wheat Field

The main meteorological variables of rainfall, wind direction, wind run, air temperature and wet bulb depression, incoming shortwave and total net radiation were recorded at site D on a Didcot Instruments Automatic Weather Station. Data was collected every 5 minutes and was stored digitally on magnetic cassette tapes with a Microdata twelve-channel logger. The same type of logger was also used to store 5 minute data of soil temperature, wind run and short-wave albedo. Apparent crop surface temperature was measured with a Barnes PRT-5 radiometer operating in the 8.0 - 14.0 μm thermal region and fitted with a 20° field of view optic. The sensor head was held vertically approximately 3 m above ground level, which provided an integrated crop temperature estimate within a circle of diameter between 0.9 - 1.0 m. Voltage output data was recorded both manually on a digital voltmeter and continuously on a Chessel chart recorder. The radiometer was calibrated along with all of the other infra red radiometers used in the experiment on the same black body temperature calibration rig. Crop emissivity values were determined experimentally in order to derive real crop temperatures. In addition to the automatically recording instrumentation, manual measurements were taken every three hours prior to the overpass and then coincident with each of the overpasses. At site D, 3 replicate sets of 8 manually-read tensiometers were provided by the University of Hanover and a variety of mercury thermometers provided replicate soil and crop temperature profiles.

A secondary site in the wheat plot, site G, was equipped only with manually-read soil and crop temperature profile thermometers. Daily

maximum and minimum surface temperature thermometers at sites D and C provided an additional check on temperature variability between sites. Bowen ratio was determined at site C by 'Fluxatron' eddy correlation apparatus with sensors set at 4.7 m above ground level.

Barley Field

Whilst the installation of instruments in the wheat and sugar beet fields was fairly straightforward, problems were encountered in the barley field as a result of the height and fragility of the crop. Special care had to be taken to ensure that radiometers were positioned over undisturbed vegetation and the installation of soil and crop thermometers inevitably caused a varying degree of disturbance of the natural vegetation cover. Ideally, such instrumentation should have been installed several months earlier, before germination of the barley, but this was not possible.

The instrument set-up at site K was very similar to that previously described of site D on the wheat field, with meteorological, soil temperature and albedo measurements being recorded automatically at 5 min. intervals. A series of 5 mercury thermometers gave some measure of the crop temperature profile whilst crop surface thermal emission was recorded continuously with a Barnes Instatherm (8 - 80μm) infra red radiometer mounted vertically over the crop. However, the narrow field of view of the optic (2.8^{o}) meant that only a spot surface emission sample could be obtained. 3 replicate sets of 8 tensiometers were provided by the University of Hanover and these, along with the other manual instruments were read every 3 hours prior to and after the aircraft overpasses.

A secondary set of soil and crop temperature profiles were measured within the barley at site I and sensible heat flux was measured, as on the wheat and sugar beet sites, with 'Fluxatron' equipment which was installed at a height of 4.9 m above ground level.

Soil sampling

To examine for small-scale variations of soil moisture a random grid comprising 27 soil sampling points was set up over the three fields. During the campaign these sites were surveyed to ease location on image and map and visited on a number of occasions to take surface soil cores. These constant volume cores were tinned, double-bagged and removed to Hanover where they were weighed, dried at 110^{0}C for 24 hours, and reweighed to give both gravimetric and volumetric soil contents. Sample sets were taken on several days prior to the flight and also immediately after both daytime and nighttime aircraft overpasses.

Conclusions

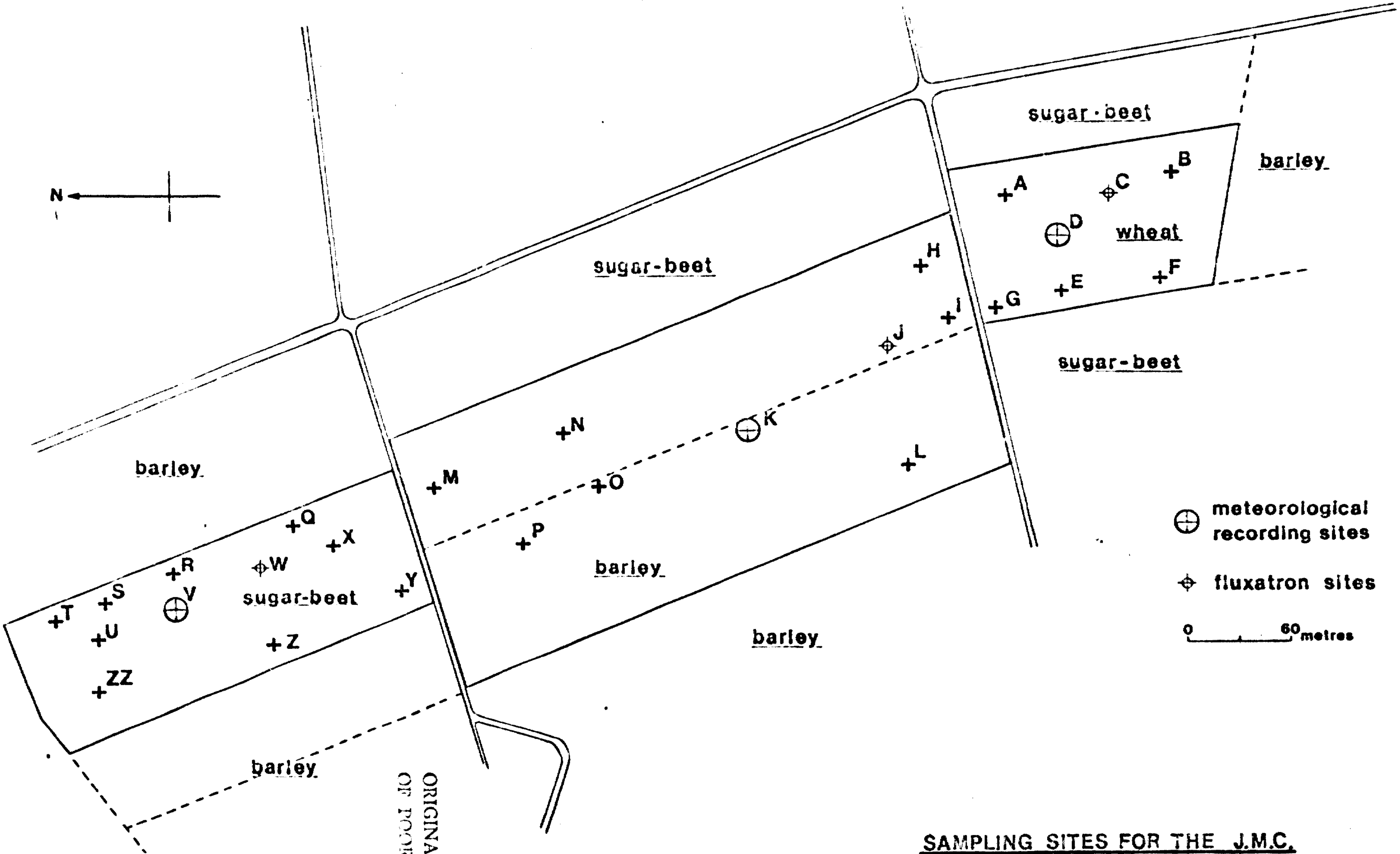
Given that the instrumentation used by the UK groups for the JMC was all that was available at the time, there appears in retrospect to be little else which could have been done to improve on the qualty of the data collected, except perhaps through the use of additional ground personnel, which would have enabled the manual instruments to be read more quickly and the Portable Multiband Radiometer to be used at the time of aircraft overpasses. During this type of measurement programme, data output from the automatically recording instrumentation would have been more suitable in a visual form eg

paper tape, rather than being recorded on magnetic tape. This would have prevented a loss of data which occurred on one of the logging systems as a result of solar overheating of the instrument case.

At the time of aircraft overpasses, ground staff found it difficult to distinguish between aircraft manoeuvres over the test site and actual overpasses when the scanner was in operation, this being especially difficult when the aircraft was operating at the highest altitudes. This could be overcome in the future by the use of more comprehensive ground communication facilities.

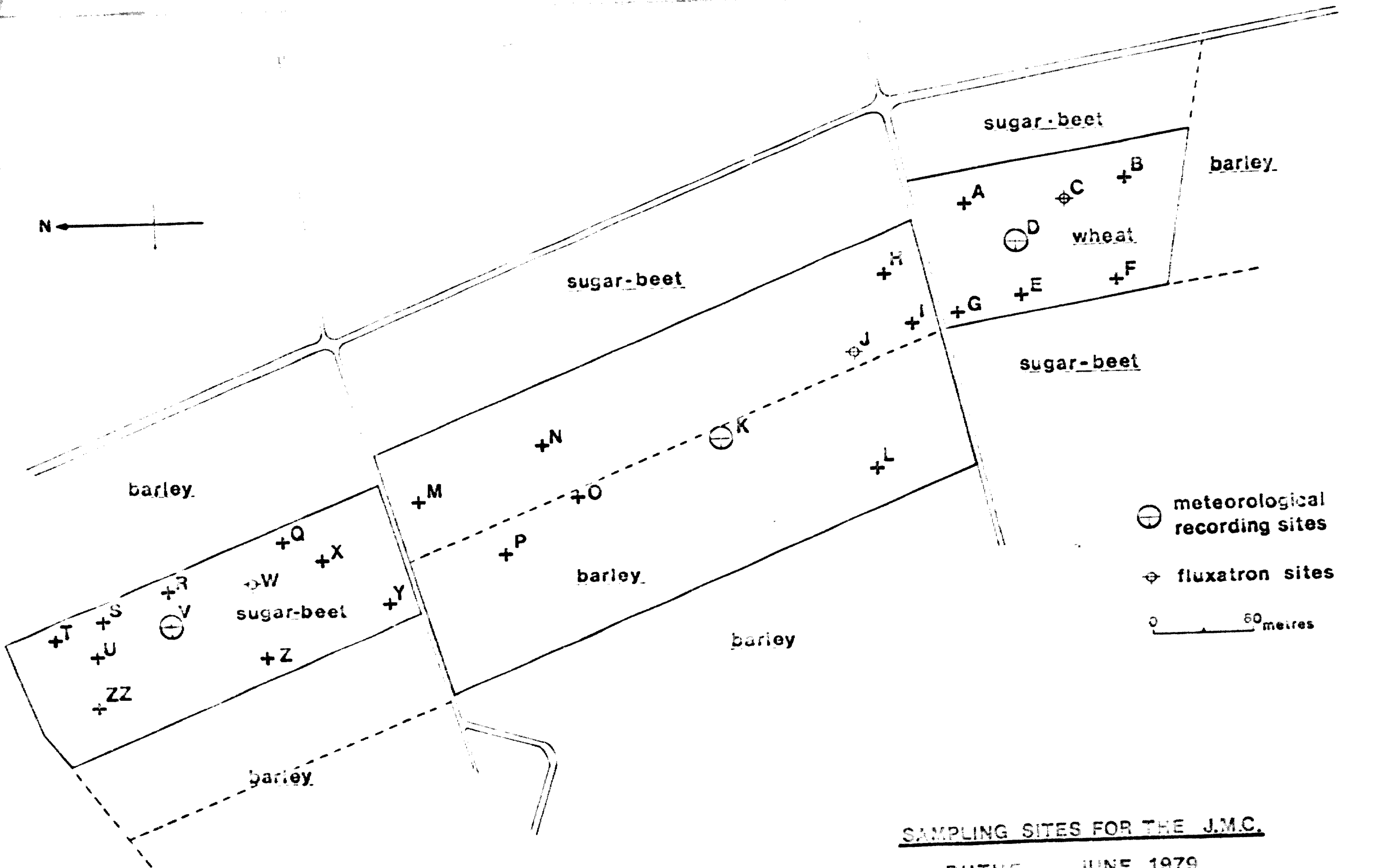
Initial data examination shows that during the night of the flight ie $\sim$ 0500 on 22 June 1979 there was a period of heavy rain. It is thus apparent that during the 24 - hour period containing the flights, weather conditions were not stable and this may invalidate certain assumptions used in applying the soil moisture and atmospheric models for the correction of infra red surface temperatures.

It is believed that the Joint Measuring Campaign should provide useful data for the investigation of problems of interest to Tell-us participants. The concentration of such a large amount of instrumentation over the test area permitted local variations to be investigated and offered the only real opportunity during the Tell-us investigation of siting several data collection points within a satellite pixel and in addition, of equipping neighbouring pixels.



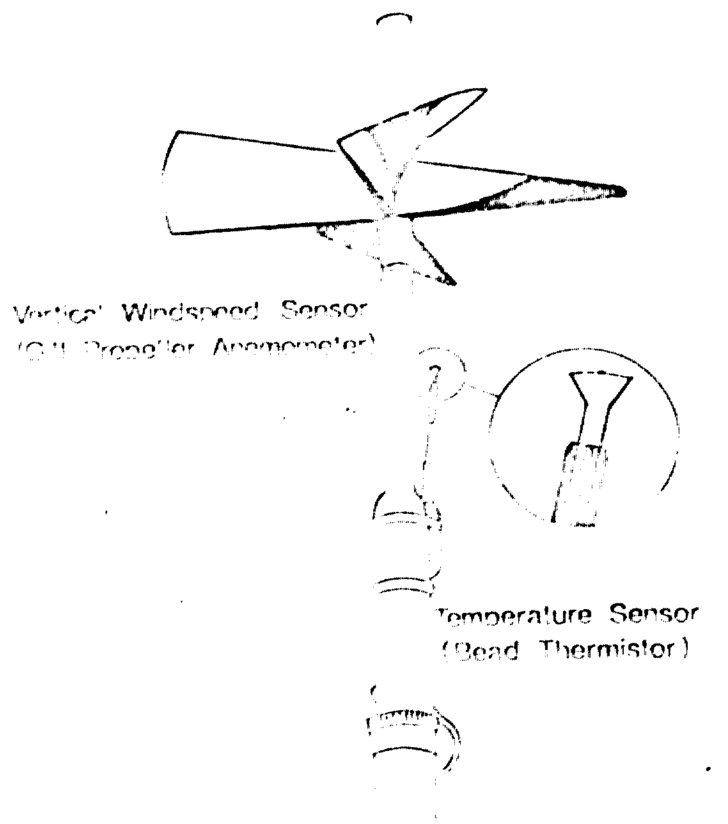
SAMPLING SITES FOR THE J.M.C.

RUTHE JUNE 1979



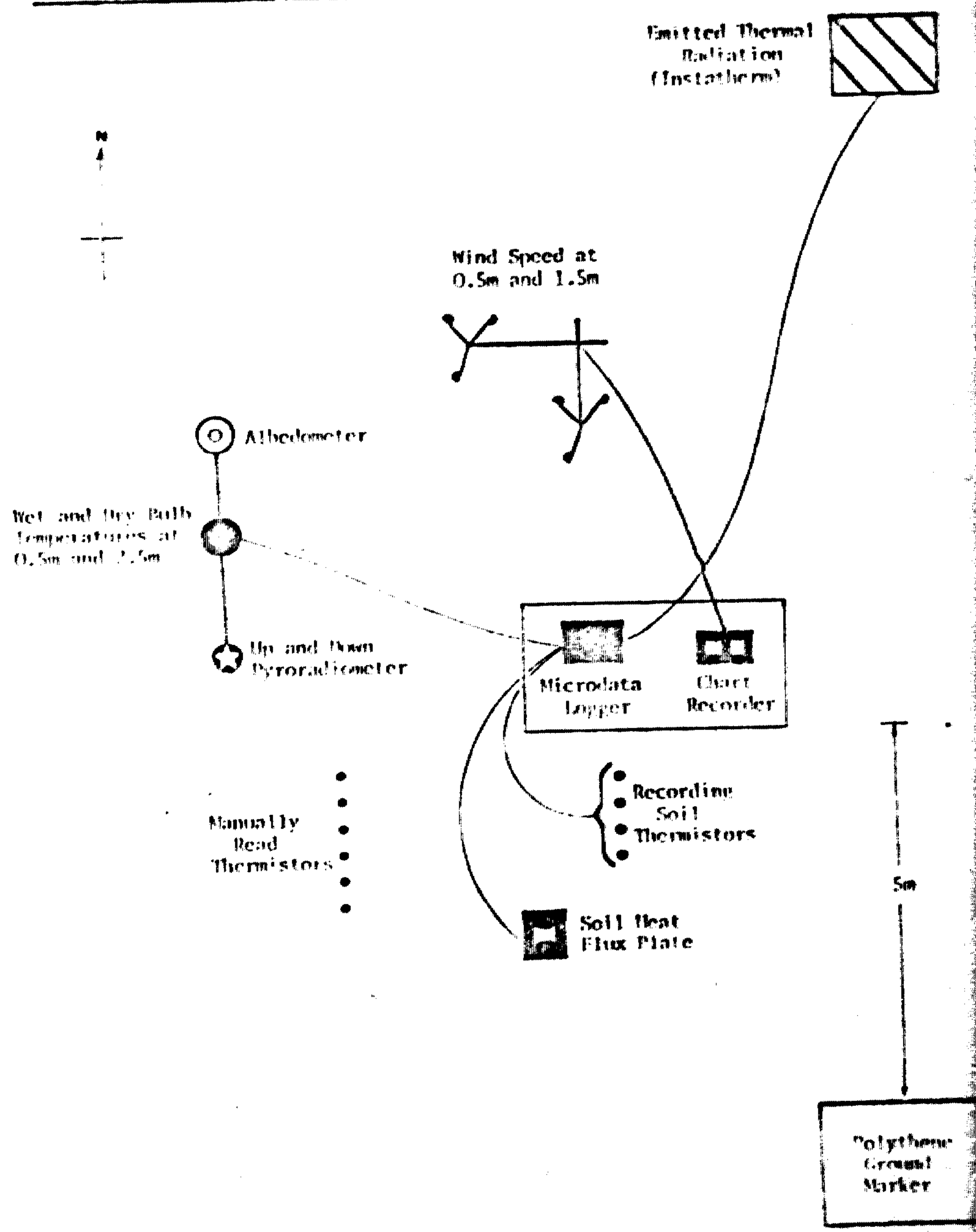
SAMPLING SITES FOR THE J.M.C.

RUTHE JUNE 1979

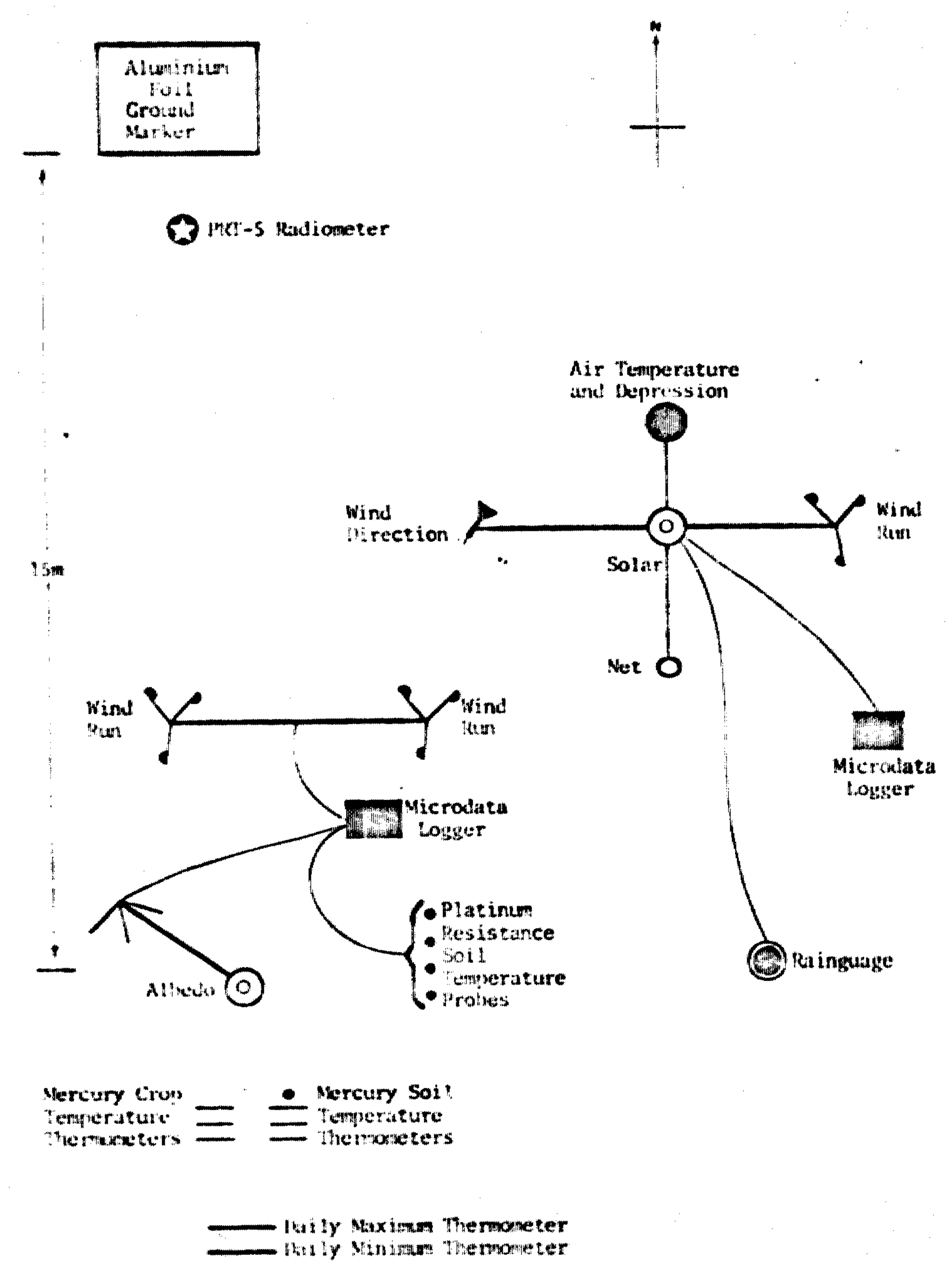


Schematic diagram of the 'Fluxatron' eddy correlation apparatus.

MAIN SUGAR BEET INSTRUMENTATION - SITE V



MAIN WHEAT INSTRUMENTATION - SITE D



MAIN BARLEY INSTRUMENTATION - SITE K

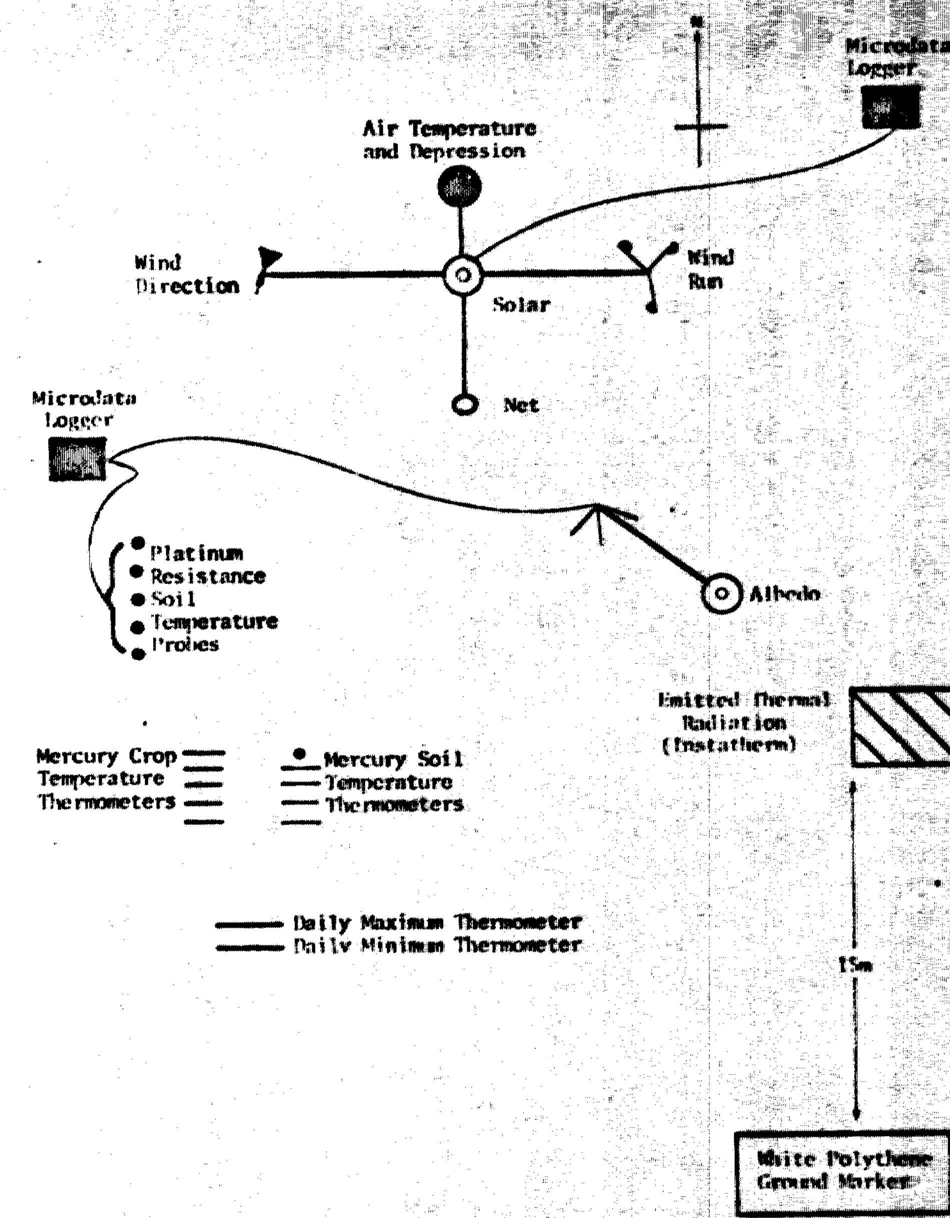


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TABLE 1. BRITISH INSTRUMENTATION FOR J M C RUTHE

Site	Measurement	Instrument type	Frequency of Measurement	Sensor Height Rela[tive] to Ground Level
WHEAT FIELD				
A	Soil sample point	None	Varied	$\Sigma^{0}_{-0.05}$ m
B	Soil sample point	None	Varied	$\Sigma^{0}_{-0.05}$ m
C	Sensible heat flux	'Fluxatron' eddy correlation apparatus	15 min average	+ 4.7 m
D		Didcot automatic weather station recording the following:		
	(1) Incoming shortwave (0.3 µm - 2.5 µm)	Kipp and Zonen	5 min	+ 3.0 m
	(2) Net total radiation (0.3 µm - 80 µm)	DRN 101	5 min	+ 1.3 m
	(3) Wind run	DWR 201 anemometer	5 min	+ 2.0 m
	(4) Wind direction	DWD 102 wind vane	5 min	+ 2.0 m
	(5) Rainfall	DR6/1 tipping bucket	5 min	+ 0.3 m
	(6) Wet and dry air temperature	Platinum resistance thermometers	5 min	+ 1.5 m
		Microdata logger recording the following:		
	(1) Shortwave albedo (0.3 µm - 2.5 µm)	Twin Kipp and Zonen	5 min	+ 1.3
	(2) Wind run	DWR 201 anemometers	5 min	+ 1.0 m
	Wind run	DWR 201 anemometers	5 min	+ 1.5 m
	(3) Soil temperature	Platinum resistance thermometers	5 min	- 0.3 m
	Soil temperature	Platinum resistance thermometers	5 min	- 0.05 m
	Soil temperature	Platinum resistance thermometers	5 min	- 0.03 m
	Soil temperature	Platinum resistance thermometers	5 min	- 0.01 m
	Soil temperature	Mercury in wax thermometer	3 hourly	. 0.6 m
	Soil temperature	90° Mercury thermometer	3 hourly	- 0.1 m
	Soil temperature	90° Mercury thermometer	3 hourly	- 0.05 m
	Soil temperature	Insulated mercury thermometer	3 hourly	- 0.01 m

	Crop temperature	Mercury thermometer	3 hourly	+ 0.05 m
	Crop temperature	Mercury thermometer	3 hourly	+ 0.20 m
	Crop temperature	Mercury thermometer	3 hourly	+ 0.50 m
	Daily maximum temperature	Mercury thermometer	daily	+ 0.01 m
	Daily minimum temperature	Alcohol thermometer	daily	+ 0.01 m
	Surface thermal emittance (8 μm - 14 μm)	Barnes PRT-5 radiometer with 20° optic	Continuous	+ 3.0 m
	Soil tension	Mercury tensiometers (3 sets of 8 - University of Hannover)	3 hourly	- 0.01 to - 1.8 m
E	Soil sample point	None	Varied	$\Sigma^{0}_{-0.05}$ m
F	Soil sample point	None	Varied	$\Sigma^{0}_{-0.05}$ m
G	Soil temperature	Mercury in wax thermometer	3 hourly	- 0.6 m
	Soil temperature	90° mercury thermometer	3 hourly	- 0.2 m
	Soil temperature	90° mercury thermometer	3 hourly	- 0.1 m
	Soil temperature	90° mercury thermometer	3 hourly	- 0.05 m
	Soil temperature	Insulated mercury thermometer	3 hourly	- 0.01 m
	Daily maximum temperature	Mercury thermometer	daily	+ 0.01 m
	Daily minimum temperature	Alcohol thermometer	daily	+ 0.01 m
BARLEY FIELD				
H	Soil sample point	None	Varied	$\Sigma^{0}_{-0.05}$ m
I	Soil temperature	Mercury in wax thermometer	3 hourly	- 0.6 m
	Soil temperature	90° mercury thermometer	3 hourly	- 0.2 m
	Soil temperature	90° mercury thermometer	3 hourly	- 0.1 m
	Soil temperature	90° mercury thermometer	3 hourly	- 0.05 m
	Soil temperature	Insulated mercury thermometer	3 hourly	- 0.01 m
	Crop temperature	Mercury thermometer	3 hourly	+ 0.1 m
	Crop temperature	Mercury thermometer	3 hourly	+ 0.2 m
	Crop temperature	Mercury thermometer	3 hourly	+ 0.5 m
	Crop temperature	Mercury thermometer	3 hourly	+ 1.0 m
	Crop temperature	Mercury thermometer	3 hourly	+ 1.5 m

	Daily maximum temperature	Mercury thermometer	daily	+ 0.01 m
	Daily minimum temperature	Alcohol thermometer	daily	+ 0.01 m
J	Sensible heat flux	'Fluxatron' eddy correlation apparatus	15 min average	+ 4.9 m
K		Didcot automatic weather station recording the following:		
	(1) Incoming shortwave (0.3 μm - 2.5 μm)	Kipp and Zonen	5 min	+ 3.0 m
	(2) Net total radiation (0.3 μm - 80 μm)	DRN 101	5 min	+ 1.3 m
	(3) Wind run	DWR 201 anemometer	5 min	+ 1.5 m
	Wind run	DWR 201 anemometer	5 min	+ 2.0 m
	(4) Wind direction	DWD 102 wind vane	5 min	+ 2.0 m
	(5) Wet and dry air temperature	Platinum resistance thermometer	5 min	+ 1.5 m
		Microdata logger recording the following:		
	(1) Shortwave albedo (0.3 μm to 2.5 μm)	Twin Kipp and Zonen	5 min	+ 1.5 m
	(2) Soil temperature	Platinum resistance thermometers	5 min	- 0.3 m
	Soil temperature	Platinum resistance thermometers	5 min	- 0.15 m
	Soil temperature	Platinum resistance thermometers	5 min	- 0.05 m
	Soil temperature	Platinum resistance thermometers	5 min	- 0.03 m
	Soil temperature	Platinum resistance thermometers	5 min	- 0.01 m
	Soil temperature	Mercury in wax thermometer	3 hourly	- 0.6 m
	Soil temperature	90° mercury thermometer	3 hourly	- 0.2 m
	Soil temperature	90° mercury thermometer	3 hourly	- 0.1 m
	Soil temperature	90° mercury thermometer	3 hourly	- 0.05 m
	Soil temperature	Insulated mercury thermometer	3 hourly	- 0.01 m
	Crop temperature	Mercury thermometer	3 hourly	+ 0.05 m
	Crop temperature	Mercury thermometer	3 hourly	+ 0.2 m
	Crop temperature	Mercury thermometer	3 hourly	+ 0.5 m
	Crop temperature	Mercury thermometer	3 hourly	+ 1.0 m
	Crop temperature	Mercury thermometer	3 hourly	+ 1.5 m

	Daily maximum temperature	Mercury thermometer	daily	+ 0.01 m
	Daily minimum temperature	Alcohol thermometer	daily	+ 0.01 m
J	Sensible heat flux	'Fluxatron' eddy correlation apparatus	15 min average	+ 4.9 m
K		Didcot automatic weather station recording the following:		
	(1) Incoming shortwave (0.3 um - 2.5 um)	Kipp and Zonen	5 min	+ 3.0 m
	(2) Net total radiation (0.3 um - 80 um)	DRN 101	5 min	+ 1.3 m
	(3) Wind run	DWR 201 anemometer	5 min	+ 1.5 m
	Wind run	DWR 201 anemometer	5 min	+ 2.0 m
	(4) Wind direction	DWD 102 wind vane	5 min	+ 2.0 m
	(5) Wet and dry air temperature	Platinum resistance thermometer	5 min	+ 1.5 m
		Microdata logger recording the following:		
	(1) Shortwave albedo (0.3 um to 2.5 um)	Twin Kipp and Zonen	5 min	+ 1.5 m
	(2) Soil temperature	Platinum resistance thermometers	5 min	- 0.3 m
	Soil temperature	Platinum resistance thermometers	5 min	- 0.15 m
	Soil temperature	Platinum resistance thermometers	5 min	- 0.05 m
	Soil temperature	Platinum resistance thermometers	5 min	- 0.03 m
	Soil temperature	Platinum resistance thermometers	5 min	- 0.01 m
	Soil temperature	Mercury in wax thermometer	3 hourly	- 0.6 m
	Soil temperature	90^{o} mercury thermometer	3 hourly	- 0.2 m
	Soil temperature	90^{o} mercury thermometer	3 hourly	- 0.1 m
	Soil temperature	90^{o} mercury thermometer	3 hourly	- 0.05 m
	Soil temperature	Insulated mercury thermometer	3 hourly	- 0.01 m
	Crop temperature	Mercury thermometer	3 hourly	+ 0.05 m
	Crop temperature	Mercury thermometer	3 hourly	+ 0.2 m
	Crop temperature	Mercury thermometer	3 hourly	+ 0.5 m
	Crop temperature	Mercury thermometer	3 hourly	+ 1.0 m
	Crop temperature	Mercury thermometer	3 hourly	+ 1.5 m

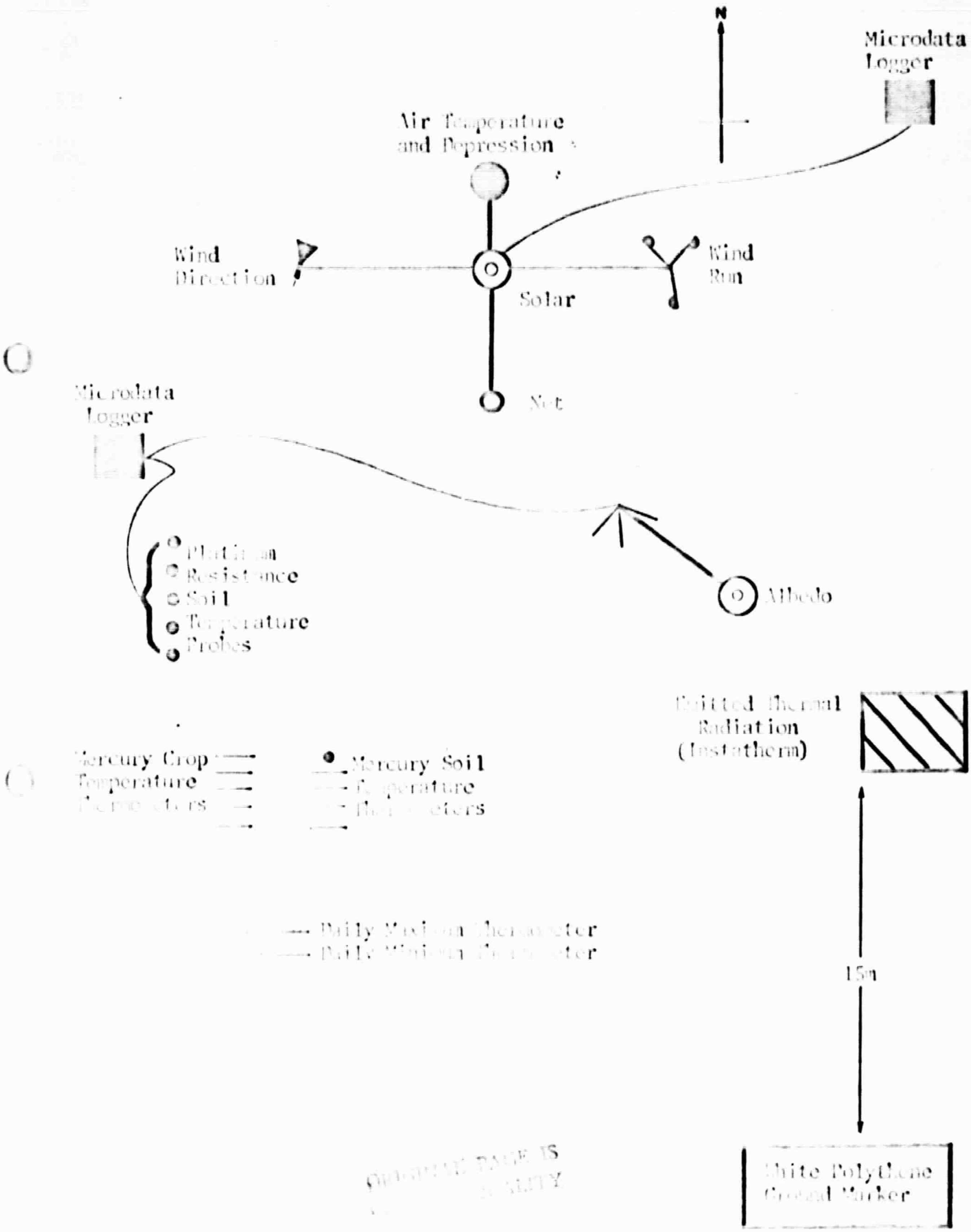
	Daily maximum temperature	Mercury thermometer	daily	+ 0.01 m
	Daily minimum temperature	Alcohol thermometer	daily	+ 0.01 m
	Surface thermal emittance (8 µm - 80 µm)	Barnes Instatherm radiometer with 3° optic	Continuous (day) Manual (night)	+ 2.0 m
	Soil tension	Mercury tensiometers (3 sets of 8 - University of Hanover)	3 hourly	- 0.01 to - 1.8 m
L	Soil sample point	None	varied	$\Sigma^{0}_{-0.05}$ m
M	Soil sample point	None	varied	$\Sigma^{0}_{-0.05}$ m
N	Soil sample point	None	varied	$\Sigma^{0}_{-0.05}$ m
O	Soil sample point	None	varied	$\Sigma^{0}_{-0.05}$ m
P	Soil sample point	None	varied	$\Sigma^{0}_{-0.05}$ m
SUGAR BEET FIELD				
Q - U	Soil sampling point	None	varied	$\Sigma^{0}_{-0.05}$ m
V	Incoming short wave radiation (0.3 - 2.5 µm)	Kipp and Zonen CM5 Solarimeter	Automatic 2 - 10 min	+ 2 m
	Outgoing short wave radiation (0.3 - 2.5 µm)	Kipp and Zonen CM5 Solarimeter	Automatic 2 - 10 min	+ 2 m
	Incoming total radiation (0.3 - 80 µm)	Schenk pyrradiometer	Automatic 2 - 10 m	+ 2 m
	Outgoing total radiation (0.3 - 80 µm)	Schenk pyrradiometer	Automatic 2 - 10 min	+ 2 m
	Dry bulb temperature	Platinum resistance thermometers	Automatic, 2-10 min	+ 0.5 m and + 1.
	Wet bulb temperature	Platinum resistance thermometers	Automatic, 2-10 min	+ 0.5 m and + 1.
	Wind speed	Vector Instruments cup anemometers	Automatic, 2-10 min	+ 0.5 m and + 1.
	Soil heat flux	Middleton Instruments Soil heat flux plate	Automatic, 2-10 min	- .075 m
	Surface thermal emittance (8 - 80 µm)	Barnes Instatherm infra red thermometer	Automatic, 2-10 min	+ 4 m

	Daily maximum temperature	Mercury thermometer	daily	+ 0.01 m
	Daily minimum temperature	Alcohol thermometer	daily	+ 0.01 m
	Surface thermal emittance (8 um - 80 um)	Barnes Instatherm radiometer with 3^{o} optic	Continuous (day) Manual (night)	+ 2.0 m
	Soil tension	Mercury tensiometers (3 sets of 8 - University of Hanover)	3 hourly	- 0.01 to - 1.8 m
L	Soil sample point	None	varied	$\Sigma^{0}_{-0.05}$ m
M	Soil sample point	None	varied	$\Sigma^{0}_{-0.05}$ m
N	Soil sample point	None	varied	$\Sigma^{0}_{-0.05}$ m
O	Soil sample point	None	varied	$\Sigma^{0}_{-0.05}$ m
P	Soil sample point	None	varied	$\Sigma^{0}_{-0.05}$ m
SUGAR BEET FIELD				
Q - U	Soil sampling point	None	varied	$\Sigma^{0}_{-0.05}$ m
V	Incoming short wave radiation (0.3 - 2.5 um)	Kipp and Zonen CM5 Solarimeter	Automatic 2 - 10 min	+ 2 m
	Outgoing short wave radiation (0.3 - 2.5 um)	Kipp and Zonen CM5 Solarimeter	Automatic 2 - 10 min	+ 2 m
	Incoming total radiation (0.3 - 80 um)	Schenk pyrradiometer	Automatic 2 - 10 m	+ 2 m
	Outgoing total radiation (0.3 - 80 um)	Schenk pyrradiometer	Automatic 2 - 10 min	+ 2 m
	Dry bulb temperature	Platinum resistance thermometers	Automatic, 2-10 min	+ 0.5 m and + 1.
	Wet bulb temperature	Platinum resistance thermometers	Automatic, 2-10 min	+ 0.5 m and + 1.
	Wind speed	Vector Instruments cup anemometers	Automatic, 2-10 min	+ 0.5 m and + 1.
	Soil heat flux	Middleton Instruments Soil heat flux plate	Automatic, 2-10 min	- .075 m
	Surface thermal emittance (8 - 80 um)	Barnes Instatherm infra red thermometer	Automatic, 2-10 min	+ 4 m

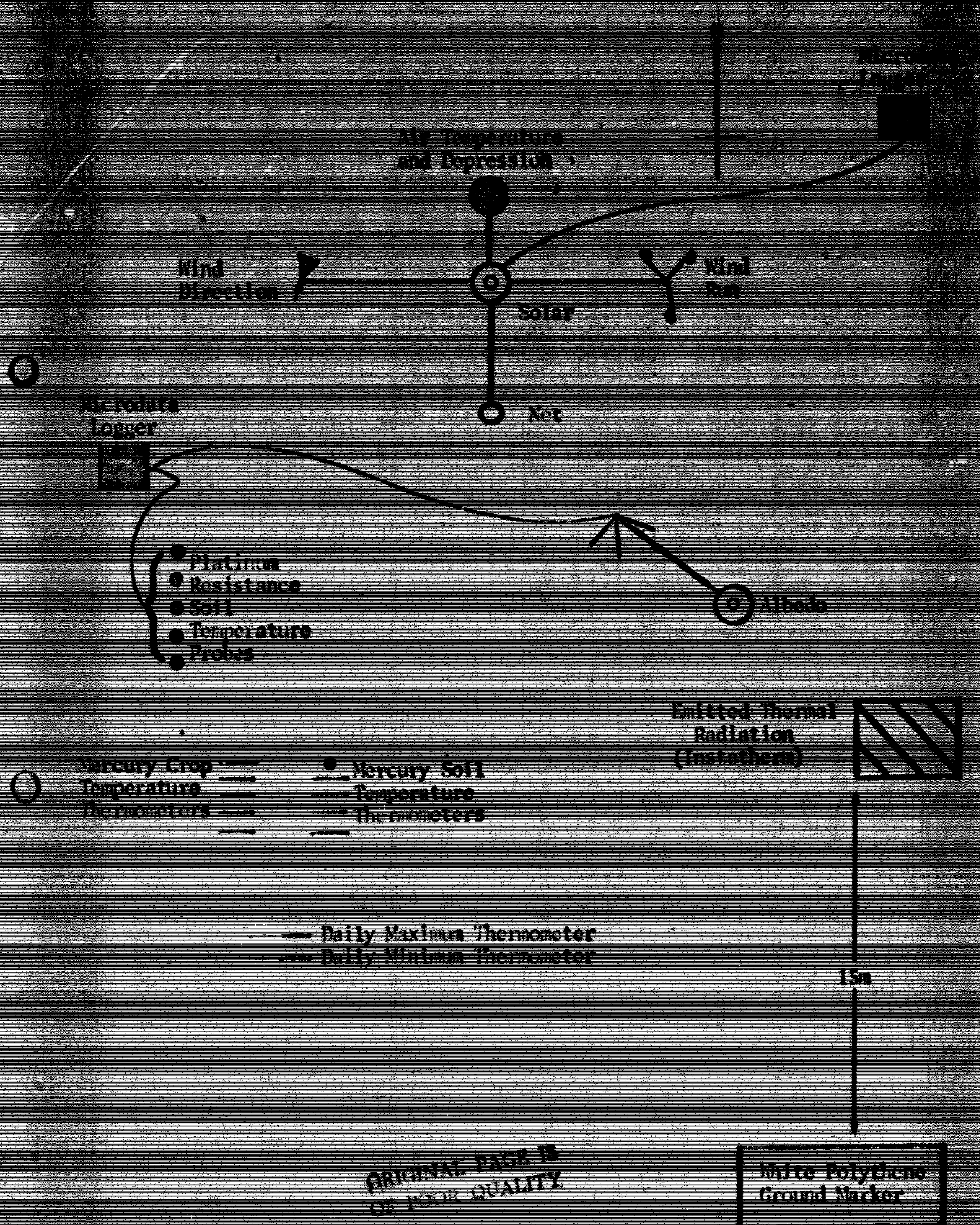
	Instatherm case temperature	YSI thermistor thermometer	Automatic, 2-10 min	+ 4 m
	Soil temperatures	YSI thermistor thermometers	(a) Automatic, 2-10 min (b) Manual, every 3 hours	-0.05, 0.10, -0.25 and -0.50 m -0.02, -0.05, -0.10, -0.20, -0.30, -0.50 m
W	Sensible heat flux	'Fluxatron' eddy correlation apparatus	15 min averaged output on paper tape	4.7 m
	Soil temperature	YSI soil thermistor thermometers	Manual, every 3 hours	- 0.02, -0.05, - 0.10, -0.20, - 0.30 and -0.50 m
X	Soil temperature	YSI soil thermistor thermometers	Manual, every 3 hours	-0.02, -0.05, - 0.10, - 0.20, - 0.30 and - 0.50 m
Y - ZZ	Soil sampling point	None	varied	$\Sigma^{0}_{-0.05}$ m

	Instatherm case temperature	YSI thermistor thermometer	Automatic, 2-10 min	+ 4 m
	Soil temperatures	YSI thermistor thermometers	(a) Automatic, 2-10 min (b) Manual, every 3 hours	-0.05, 0.10, -0.25 and -0.50 m -0.02, -0.05, -0.10, -0.20, -0.30, -0.50 m
W	Sensible heat flux	'Fluxatron' eddy correlation apparatus	15 min averaged output on paper tape	4.7 m
	Soil temperature	YSI soil thermistor thermometers	Manual, every 3 hours	- 0.02, -0.05, - 0.10, -0.20, - 0.30 and -0.50 m
X	Soil temperature	YSI soil thermistor thermometers	Manual, every 3 hours	-0.02, -0.05, - 0.10, - 0.20, - 0.30 and - 0.50 m
Y - ZZ	Soil sampling point	None	varied	$I^{o}_{-0.05}$ m

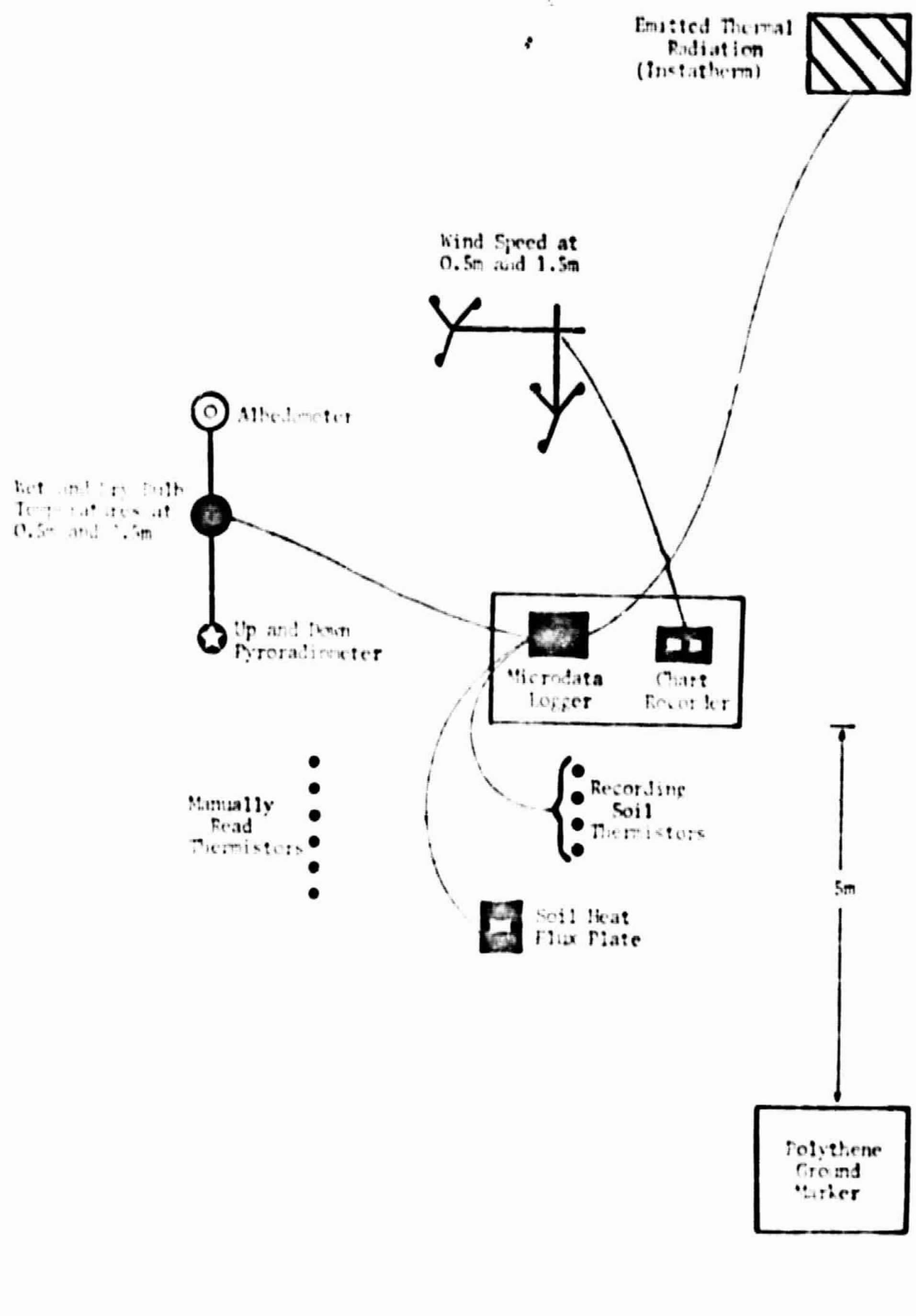
MAIN BARLEY INSTRUMENTATION - SITE K



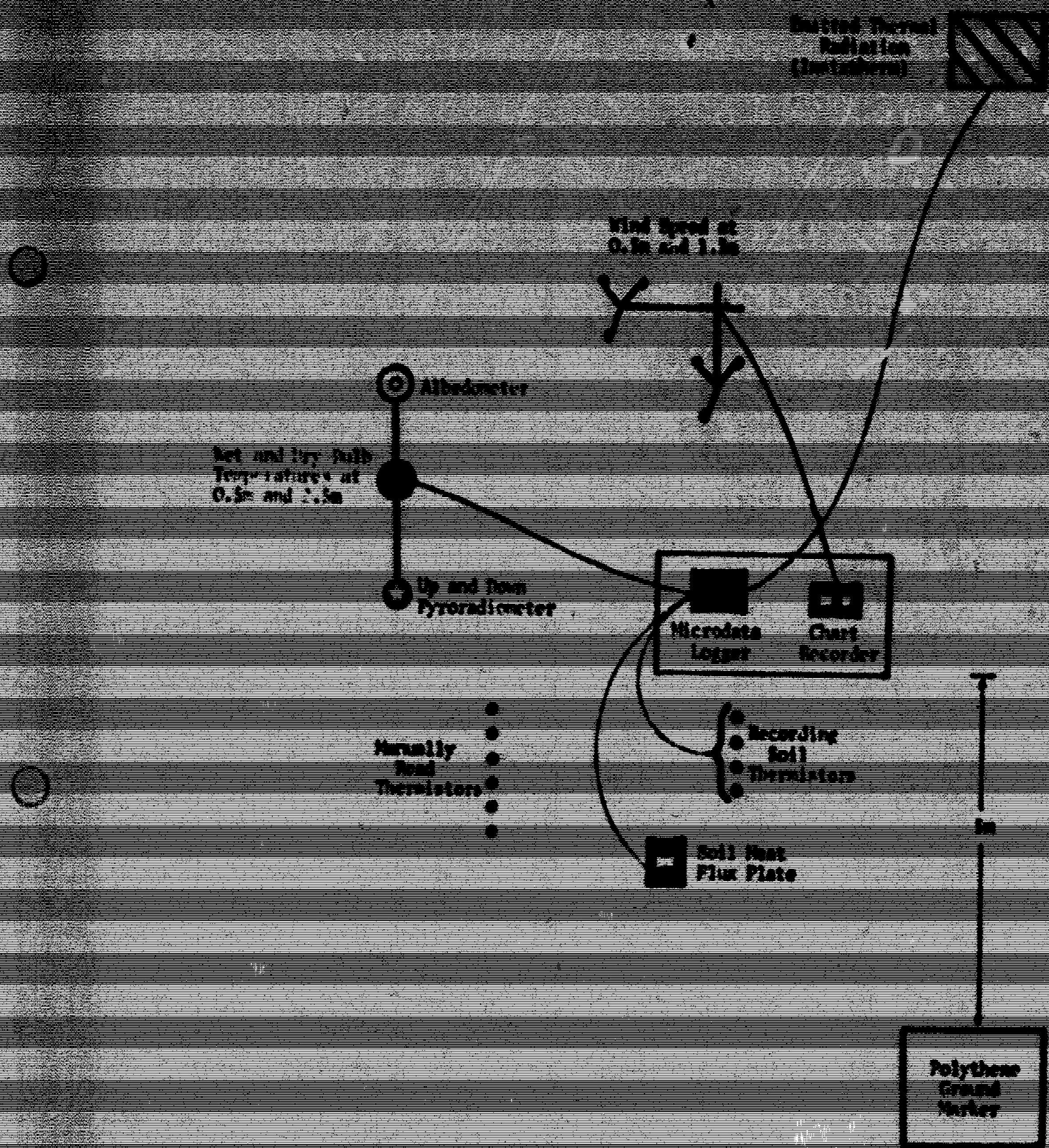
BARLEY INSTRUMENTATION - SITE K



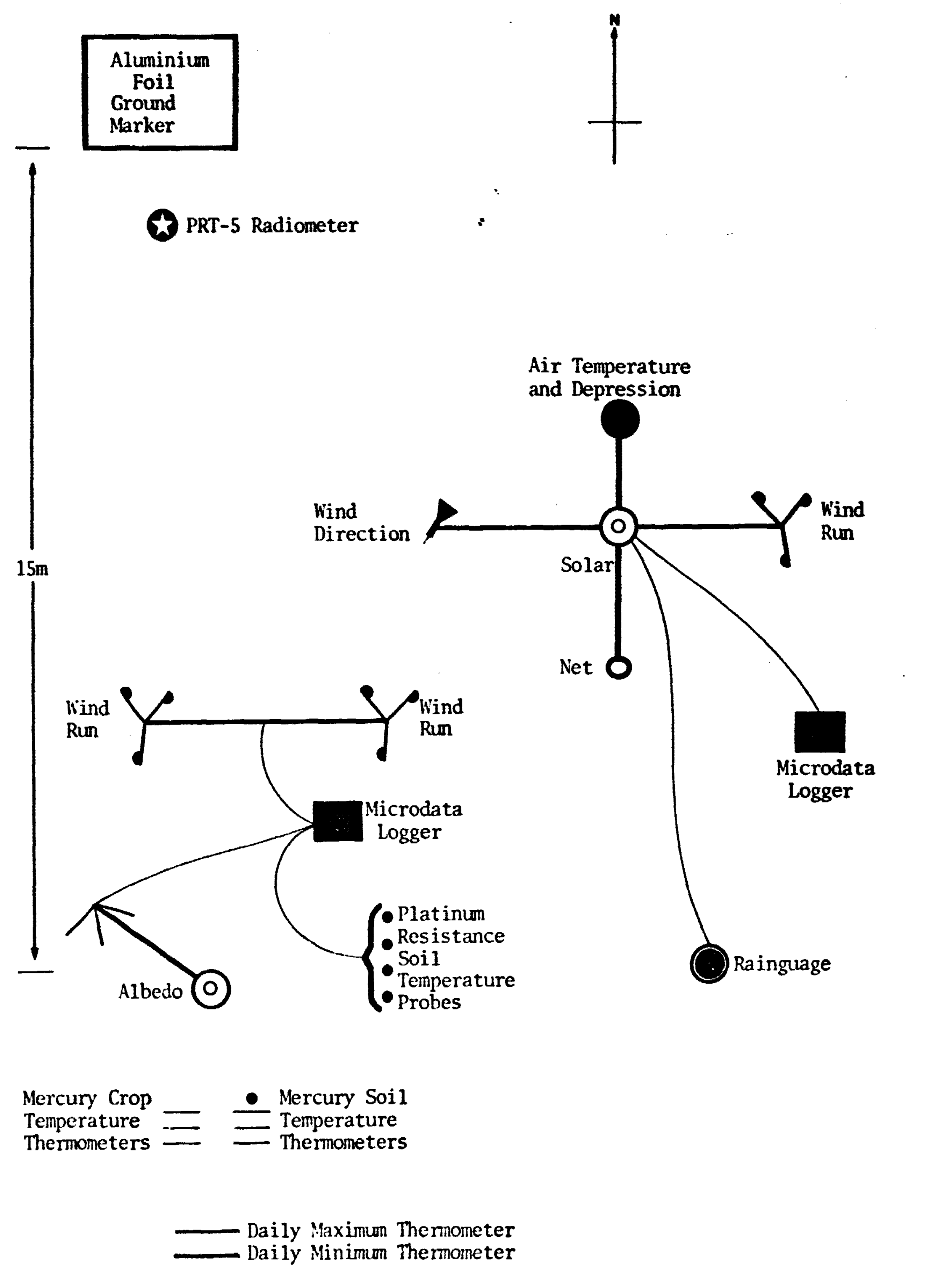
MAIN SUGAR BEET INSTRUMENTATION - SITE V



[illegible] INSTRUMENTATION - SITE V



MAIN WHEAT INSTRUMENTATION - SITE D



15. The 45 m Meteorological Tower Station Ruthe

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Location of the Station

The Institute of Meteorology and Climatology of the University of Hannover maintains an agrometeorological station at Ruthe about 15 km south of Hannover. The measuring site is situated on the alluvial middle terrace 10 to 15 m above the Leine valley (cf. fig. 1-4). The Station is located on a lawn and equipped with a variety of measuring devices. It is surrounded by a 1 m high hedge of Carpinus betulus. A number of wooden buildings - one flat barrack - are built on the northwest corner of the field. In the middle of the lawn stands a 45 m tower equipped for the measurement of radiation, temperature and humidity data and another 10 m tower with a mechanical wind recorder after Woelfle.

Instrumentation

The meteorological measuring instruments which were employed during the campaign are compiled in Table 1. The values of the soil temperature, air temperature, global radiation and radiation balance were collected with use of a digital recording station. At the end of a 60 minute measuring period (incl. 3 min. calculation time) the individual deviced are scanned and the values are directed to a pre-programmed compiler. The connected teletype prints the data on paper of DIN A 4 size. In addition the data are compiled on perforated tape.

The wind speed was measured by cup anemometers in 45, 20, 10 and 2 m height. The values were registered by two two-channel line recorders. The wind speed was determined additionally in 10 m height with a mechanical wind recorder after Woelfle. With that instrument the wind direction was also measured.

A KT 4 radiometer (Heimann Company) was used for the remote sensing of the surface temperatures of the meadow. A measuring sonde consisting of a Cassegrain-mirror objective with a high focal length, a built in 30 s^{-1} oscillating modulator, a reference radiation source, a highly sensitive Heimann metal layer bolometer for a 0.6 µm to 40 µm wavelength interval, a spectral filter for a 8 um to 14 µm wavelength range, a test area marking, an amplifier with digital and analogous indication and a test radiator belong to the standard equipment of the KT 4.

The testing method of the KT 4 is based on the measurement of differences in radiation. For the measuring procedure a temperature range from 0°C to 100°C was chosen. The emittance can be regulated between 0.10 and 1.00. During the measurements the emittance was set equal to 1. The distance from the target was 1 meter, with an aperture of 10 mm at a distance ratio of 100 : 1. For distances greater than 1 m the indication becomes independent from the distance.

Recording and evaluation

Because normally only hourly means or hourly sums respectively of soil temperatures and radiation parameters are collected, an evaluation of 15 min. or 2 min. periods had to be worked out. In addition most of the air temperature and wet-bulb temperature values were recorded by compensographs of the Hartmann and Braun Co. and the Siemens Co. respectively. Hence it was possible to record 2-minute and 15-minute values as well as hourly values. The hourly values were calculated from the arithmetic means of the 15-minute values. Since the wind data were registered by line recorders all of the three intervals could be evaluated, too.

On the organisation of the measuring site

Measurements were begun at the station in Ruthe in 1967; the digital recording being introduced in 1976. For the Tellus JMC

however extensive additional mountings as well as calibration of the measuring instruments had to be carried out. This work would have not been possible without the collaboration of the co-workers of the Institute, who were engaged in the measurements. The help of the engineering employee Mr. Rainer Surkow as a electrotechnician and the numerous overtime hours of the foreman of the Institute, Mr. Roland Dybizbanski were very important. At this point thanks are to be assured to all of them for their great engagement.

LEGEND TO FIGURES AND TABLES OF CHAPTER 15

Fig. 1	Topographic map, scale 1:50000
Fig. 2	Topographic map, scale 1:5000
Fig. 3	Topographic map, scale 1:3200
Fig. 4	Topographic map, scale 1:500
Table 1	List of measuring devices on the 45 m weather tower

Fig. 15.1

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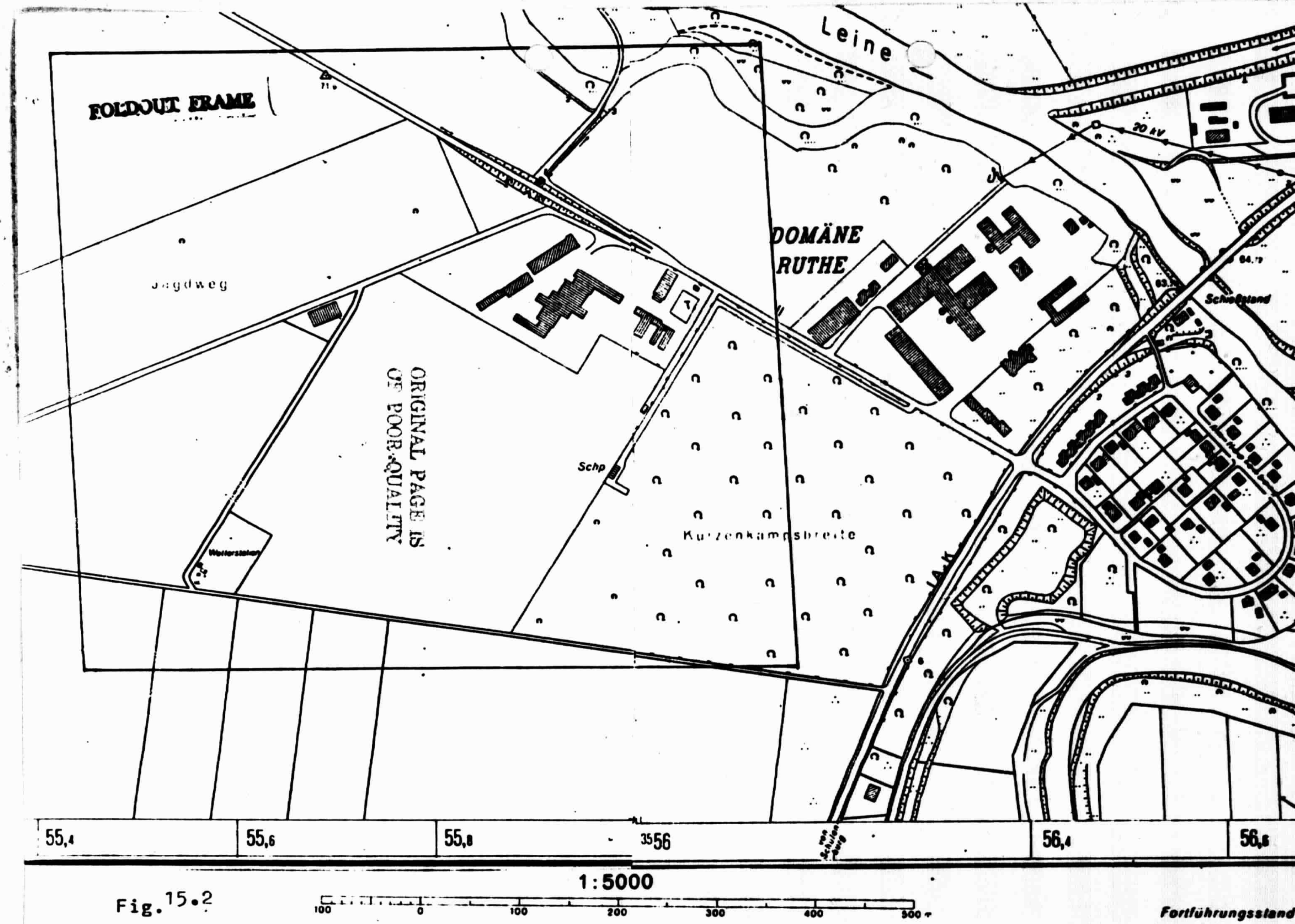
1: 50000 (2 cm der Karte = 1 km der Natur)

Meter 1000 500 0 1 2 3 4 5 Kilometer



FOLDOUT FRAME

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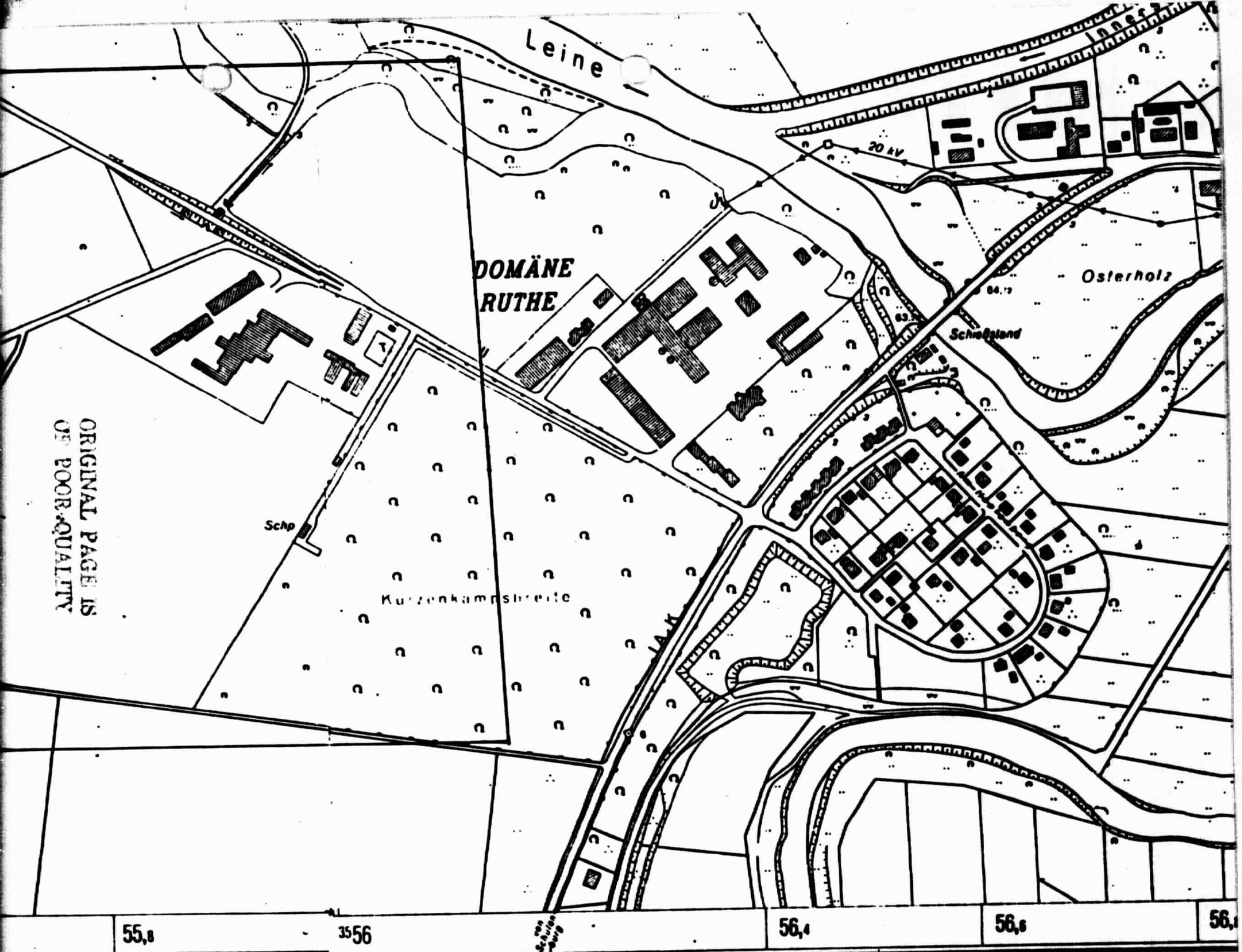
Fig. 15.2

Herausgegeben 1978



1:5000

0 100 200 300 400 500 m

Katasteramt Hildesheim

Herausgegeben 1978

FOLDOUT FRAME

Fortführungsstand:

Fortgeführt 1977

Nachträge

Redaktionelle Änderungen

FOLDOUT FRAME

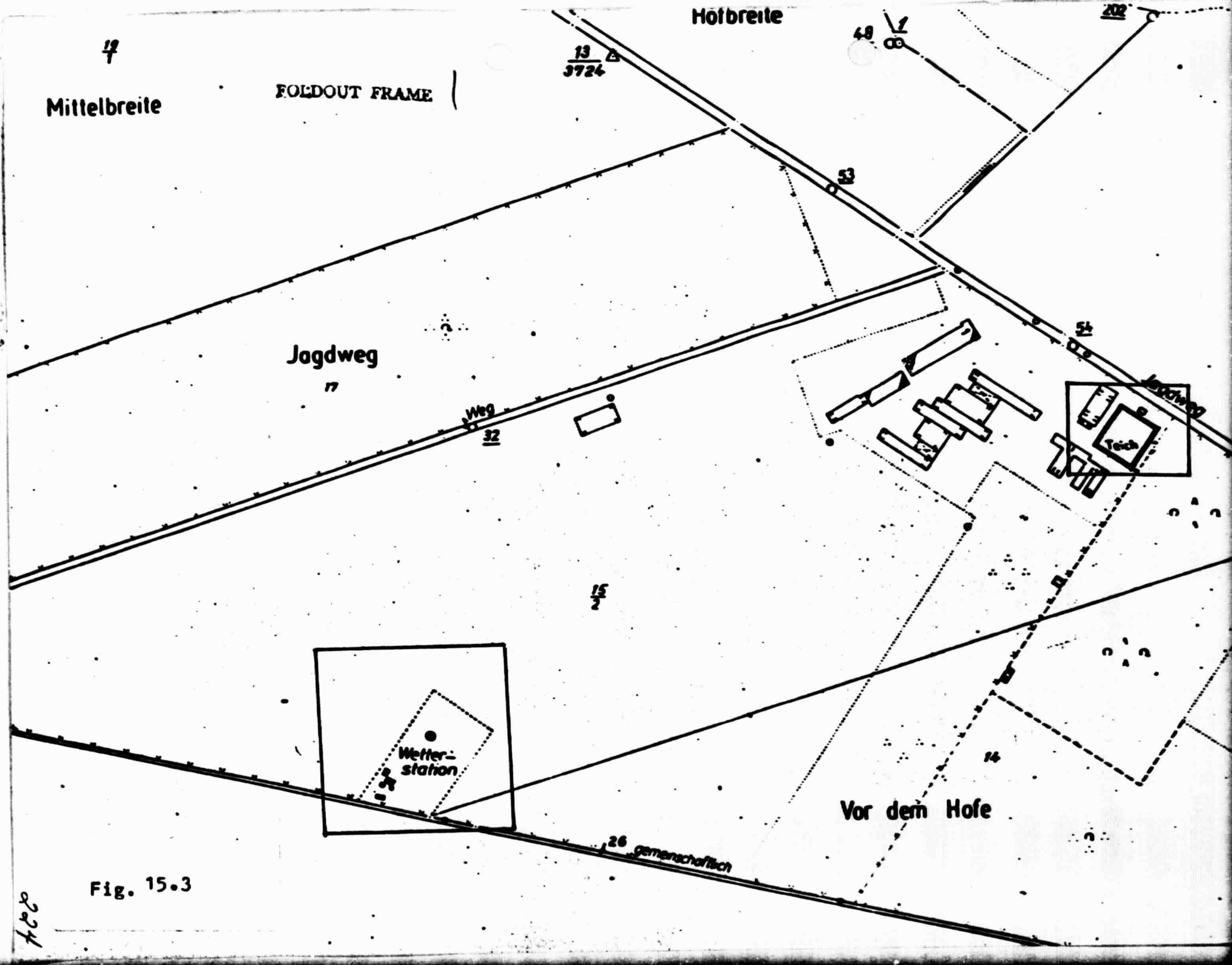
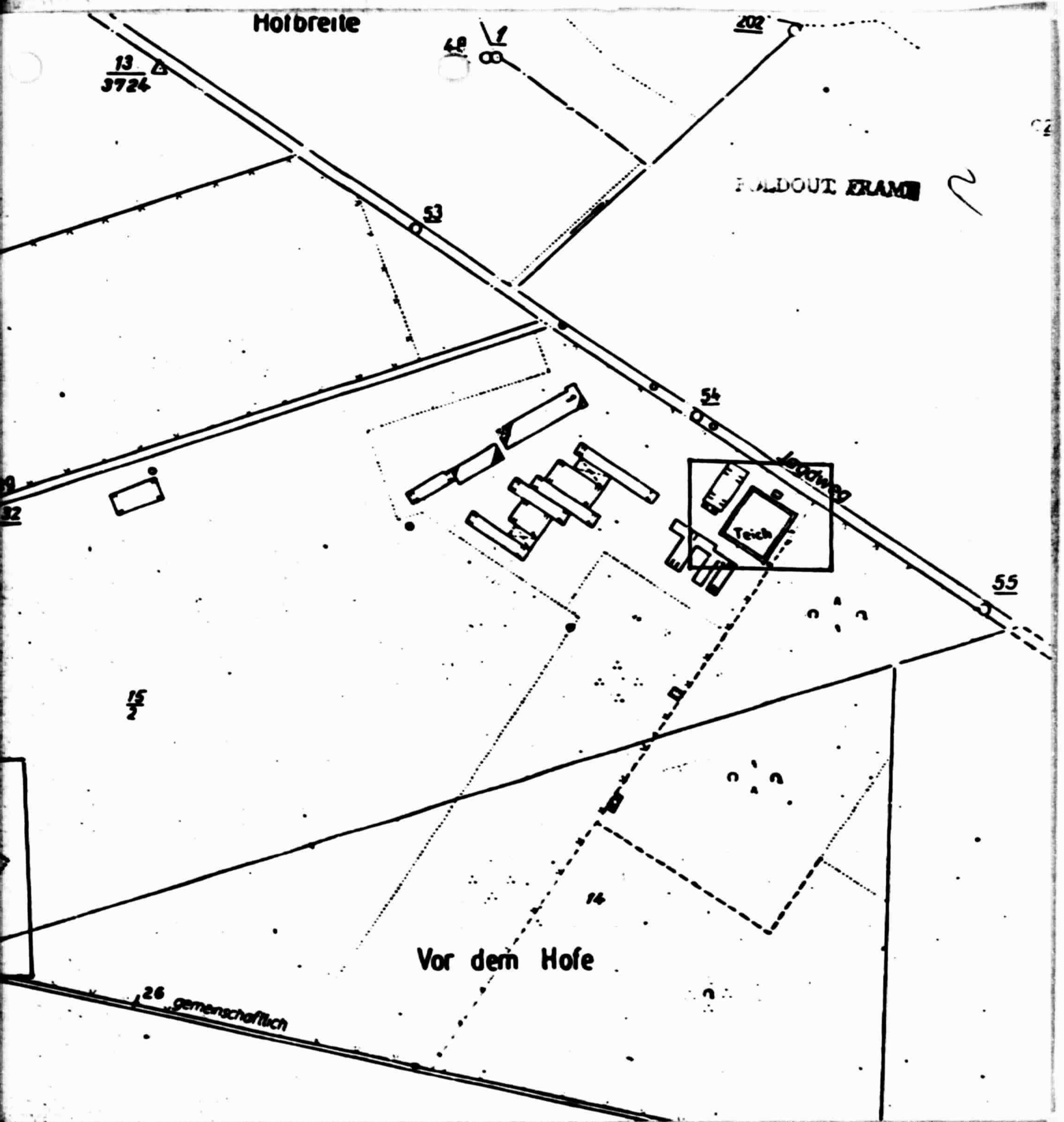


Fig. 15.3



Hofbreite
13
3724
48
1
202
53
54
55
Jagdweg
Teich
15
2
14
Vor dem Hofe
26 gemeinschaftlich
32

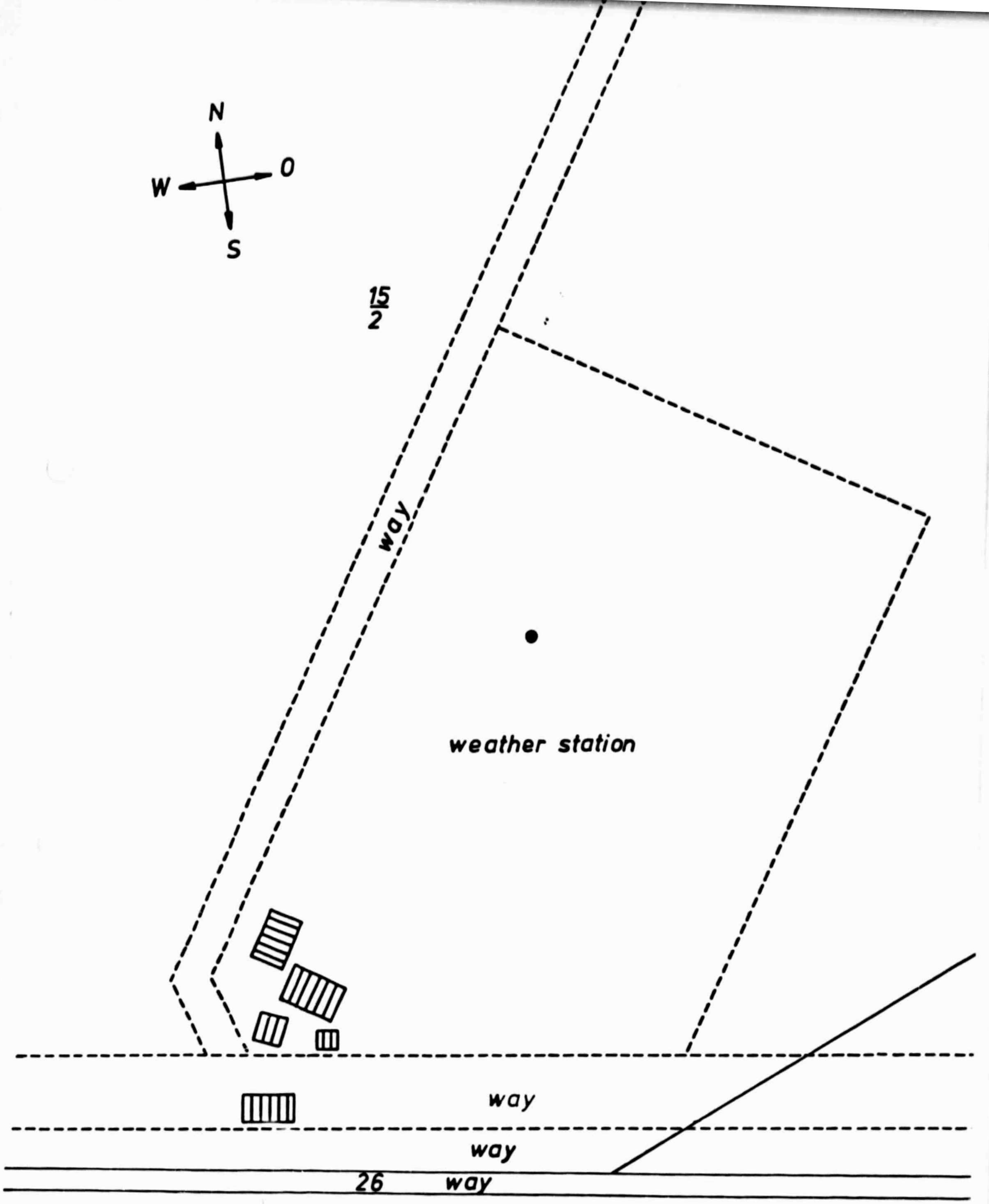


Fig.15.4

SCALE 1: 500

Tab. 15.1 List of measure points at the Agrometeorological station

measure point	
1	air temperature 50m
2	wet bulb temperature 50m
3	air temperature 20m
4	wet bulb temperature 20m
5	air temperature 10m
6	wet bulb temperature 10m
7	air temperature 2m
8	wet bulb temperature 2m
9	air temperature 0.5m
10	wet bulb temperature 0.5m
11	soil temperature -0cm
12	soil temperature -1cm
13	soil temperature -2cm
14	soil temperature -5cm
15	soil temperature -10cm
16	soil temperature -20cm
17	soil temperature -100cm
20	albedo of the meadow (Moll Gorczinsky)
21	albedo of the road (Moll Gorczinsky)
22	short-wave radiation (Moll Gorczinsky)
23+26	short-wave + long wave radiation (Schulze)
24	short-wave + long-wave albedo of the meadow
25	short-wave + long-wave albedo of the road
30	surface temperature of the meadow (KT 4)
40	wind speed at 45m (cup anemometer)
41	wind speed at 20m (cup anemometer)
42	wind speed at 10m (cup anemometer)
43	wind speed at 2m (cup anemometer)
44	wind direction at 10m (Woelfle)
45	wind speed at 10m (Woelfle)

16. The Irrigation Pond

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Description of the Test Site (Field Nr. 0) at the Experiment Farm of the University of Hannover at Ruthe

Measurements were conducted at a 28 m x 28 m sized water basin, the irrigation pond (Fig. 1). The sides and the bottom of the basin are paved with asphalt. The cross section, the longitudinal section and the topview are shown in Fig. 2a and 2b. The deepest point of the pond is located 170 cm in front of a pump house. Here the side wall slopes steeper than on the other sides. The bottom of the basin on the opposite side is about 130 cm below the surface. The basin is filled with water from the Innerste Creek and a nearly constant water level is maintained. Because of the mainly dry weather during the Measuring Campaign water was taken from the pond on some days for irrigation purposes. In order to compensate the resulting deficit water was refilled from the Innerste Creek. A 50 cm wide bare shore is followed by a 10 m wide stripe grown with conifers and soil covering plants. The vegetation however is not so high as to shade the test side (Fig. 3). On the northeastern side of the pond the pump house in which the recording devices were placed can be found. A barrack is situated 10 m away from the pond on the northwest side.

Measurements of water and air temperature

The water and the air temperatures were measured in the middle of the pond on a 50 cm x 100 cm sized, 8 cm thick Styropore

floating plate (site A, Fig. 4). On the floating plate two Heraeus hard glass resistance thermometers were installed in 8 cm and 1 cm depth to determine the water temperature and two thermometers 1 cm and 8 cm above the water surface to measure air temperature. The sensors were oriented to the north and in addition protected against direct sunlight. The mounting of the floating plate is shown in Fig. 4.

Measurement of the Water Surface Temperature with an Infrared Radiometer

For the determination of the water surface temperature a Heimann KT 12 radiometer was used. The instrument was mounted on a 4 m long outrigger at a 6 m high mast. The mounting is shown schematically in Fig. 5. The KT 12 was employed for remote sensing of the surface temperature of the pond. A measuring sonde and an amplifier with an indicator part belong to the standard equipment. The measuring sonde contains an optical component, the highly sensitive bolometer, a low noise pre-amplifier, an oscillating modulator and a reference radiation source which is kept constant at 60°C. The amplifier is equiped with selective intensifier stages, a phase depending rectifying connection, different regulators and a test radiator. For this measuring campaign the temperature range from 0°C to 60°C was chosen. The emittance which can be regulated between 0.2 and 1.0 was set on the value 1. The spectral sensitivity ranges from 0.6 to 40 um wavelength. For the measurements a lens objective with a focal distance of 70 mm was used. At a distance of 7 m from the target the radiation from an area 32 cm in diameter is received. For objects with an emissivity of 1 the relative error in measurement of the KT 12 amounts 1.5 % from the highest temperature in the appropriate measuring range. The temperature resolution runs up to 0.5 K.

Measurement of Temperature and Humidity (Site C and D)

The dry- and wet-bulb temperature were determined by two Frankenberger Psychrometers of the Friedrichs Co. 50 cm and 200 cm above the water surface. The sensors were installed on a 2 m high aluminium construction (see Fig. 6).

Radiation Measuring Devices (Site C and D)

In order to measure the radiation a Schulze radiation balancemeter and two Moll-Gorczinsky solarimeters were installed 200 cm above the water surface. The Schulze balancemeter is measuring the total short- and longwave radiation (0.3 µm - 60 µm) from the upper and lower hemisphere. In addition the incoming and outgoing radiation can be determined separately. The global radiation and the albedo in the wavelength interval from 0.32 µm to 2.5 µm was measured with solarimeters.

Recording of the Measured Values

The recording of the measured values was carried out in an analogous way. The thermometers were connected to a Siemens twelve-channel recorder by a three-wire connection. Every two minutes a value from each thermometer was recorded.
The radiation measuring devices were connected to a Hartmann and Braun six-channel recorder (ARUKOMP) also having a 2 minute scan rate. The measured values of the KT 12 were registered on a Philips line recorder.

Evaluation of the Measured Values

For the whole period of the campaign the data were evaluated every 15 minutes. Hourly values were calculated on basis of the arithmetic average. For the period of the flight measurements all values were evaluated every two minutes. The 15-minute values and the hourly means were determined for this period by calculating the arithmetic average. During the measuring campaign there were a number of periods with equipment failures:

The six-channel recorder for radiation measurement from 16.6., 11 GMT to 17.6., 9 GMT; the temperature recording failed on June 16 from 10.30 GMT to 13.00 GMT and on the 17.6 from 22.00 GMT to 23.00 GMT. Trouble with the paper transport complicated the evaluation of the KT 12 data. The following periods could not be evaluated: 18.6, 11.00 until 19.6, 2.00 GMT; 19.6, 300 until 19.6, 4.00 GMT; 19.6, 15.00 until 19.6., 15.45 GMT; 19.6, 17.00 until 19.6., 18.00 GMT.

Acknowledgement

Thanks are due to Rainer Bollin, Petra Köster, Sabine Nasdalack, Manno Peters and Frank Schroeder for valuable assistance during the Campaign.

LEGEND TO FIGURES AND TABLES OF CHAPTER 16

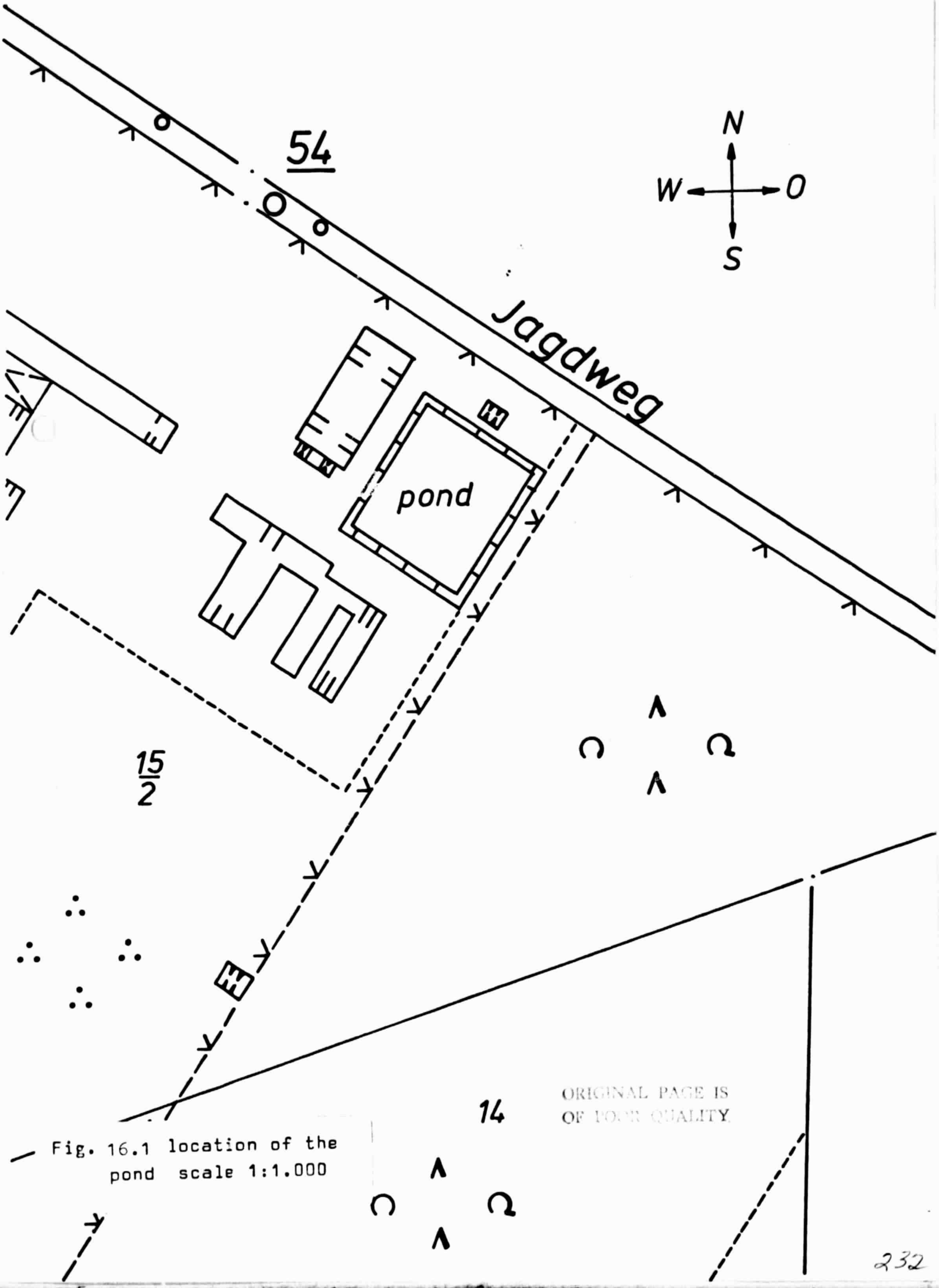


Fig. 16.1 location of the pond scale 1:1.000

TOPVIEW OF THE TEST SITE 0

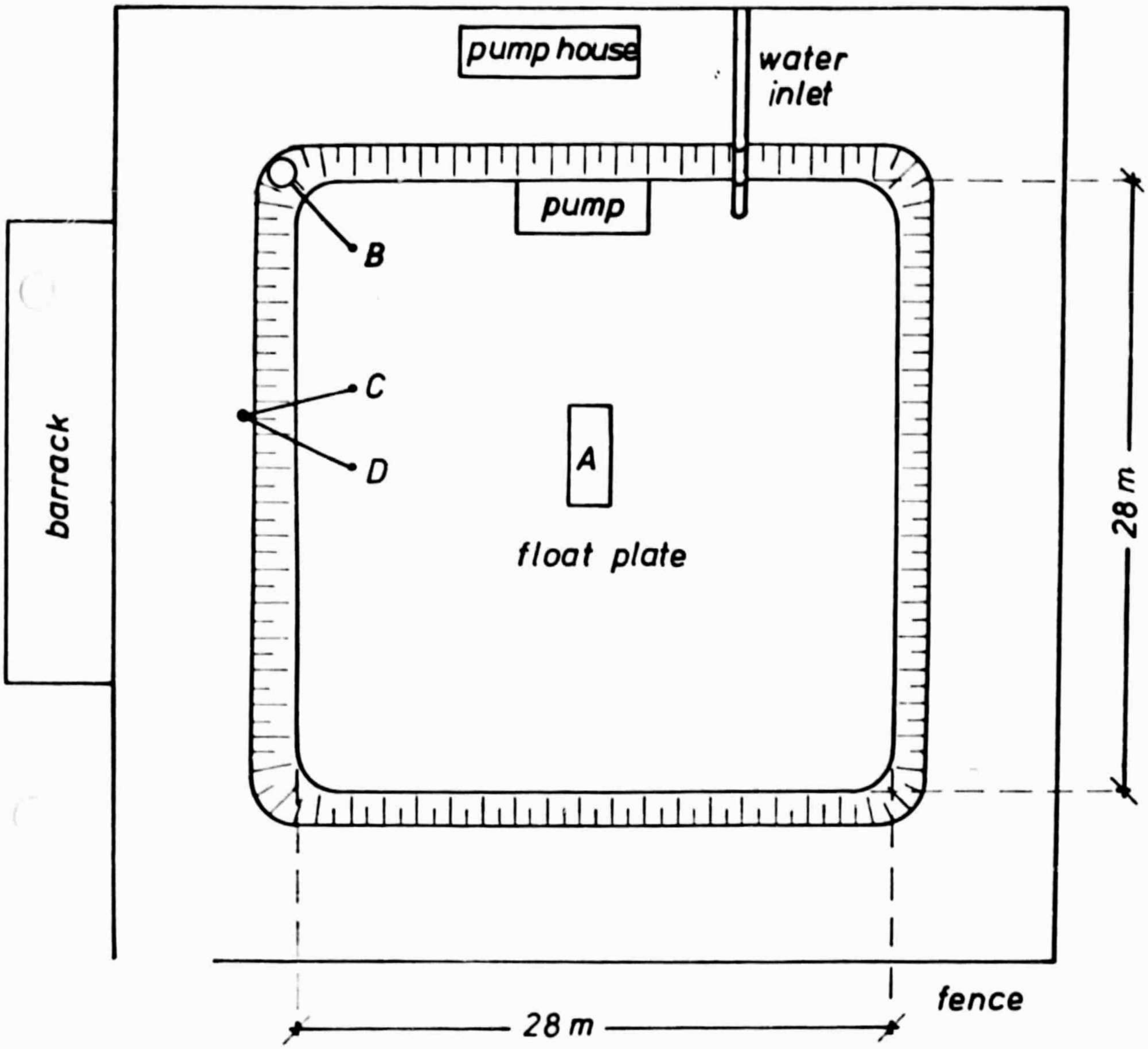
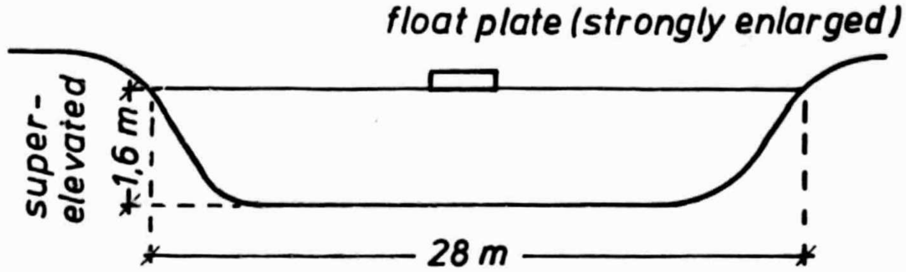


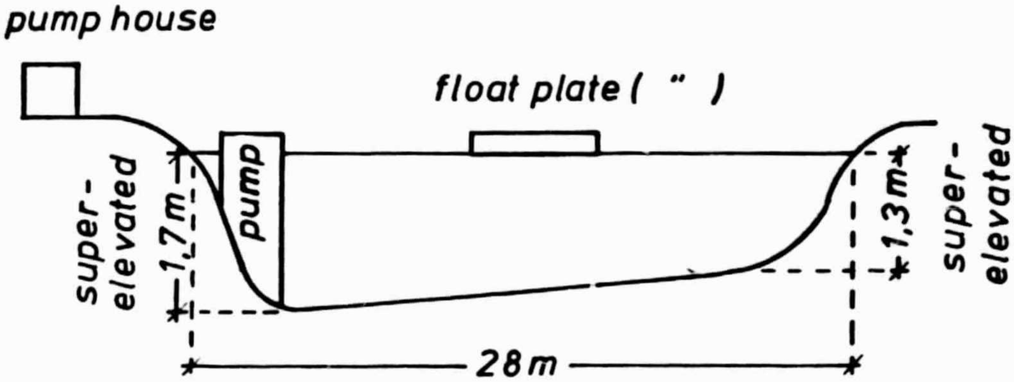
Fig. 16.2a
Test site 0

TEST SITE 0

IRRIGATION - POND



CROSS-SECTION NW-SE



CROSS-SECTION NE-SW

Fig. 16.2b
Test site 0

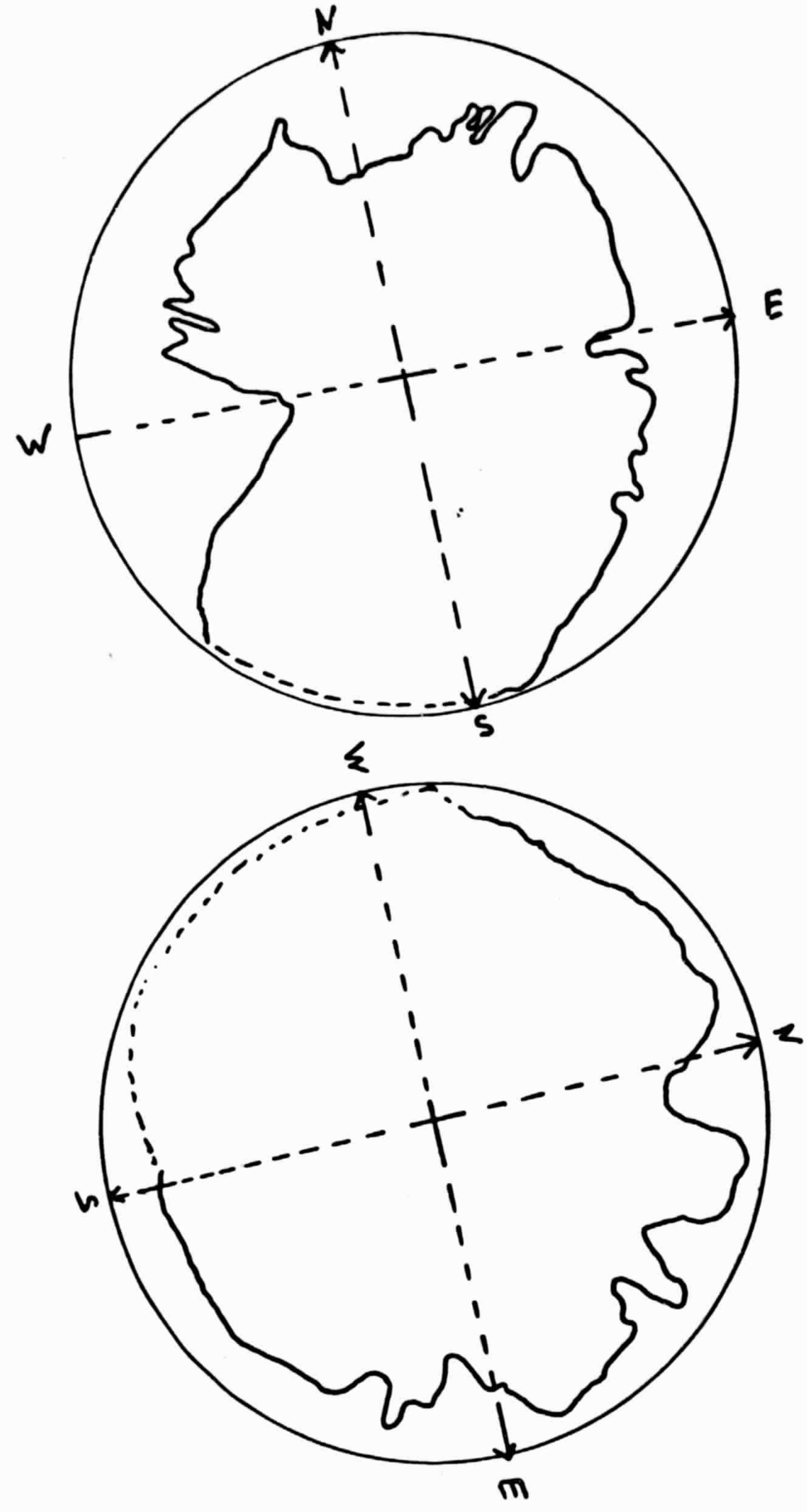


Fig. 16.3 limitation of
the horizon at O

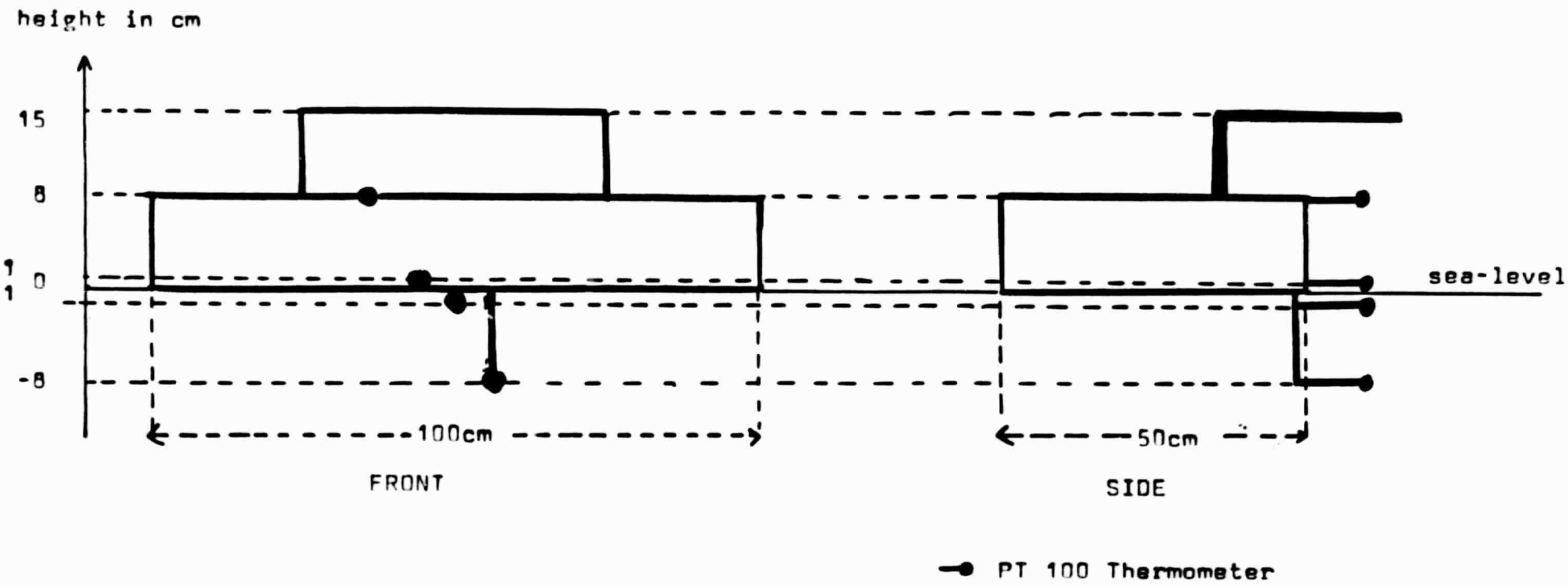


Fig. 16.4 Test site A (float plate) , schematic

MEASUREMENT POINT B

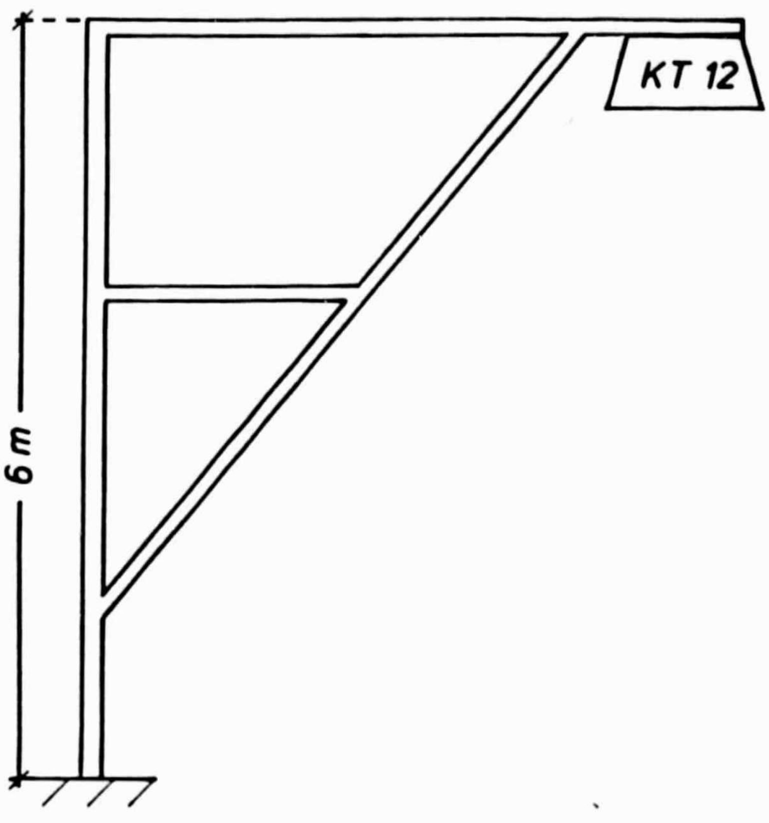


Fig. 16.5 Test site B
(6m mast) schematic

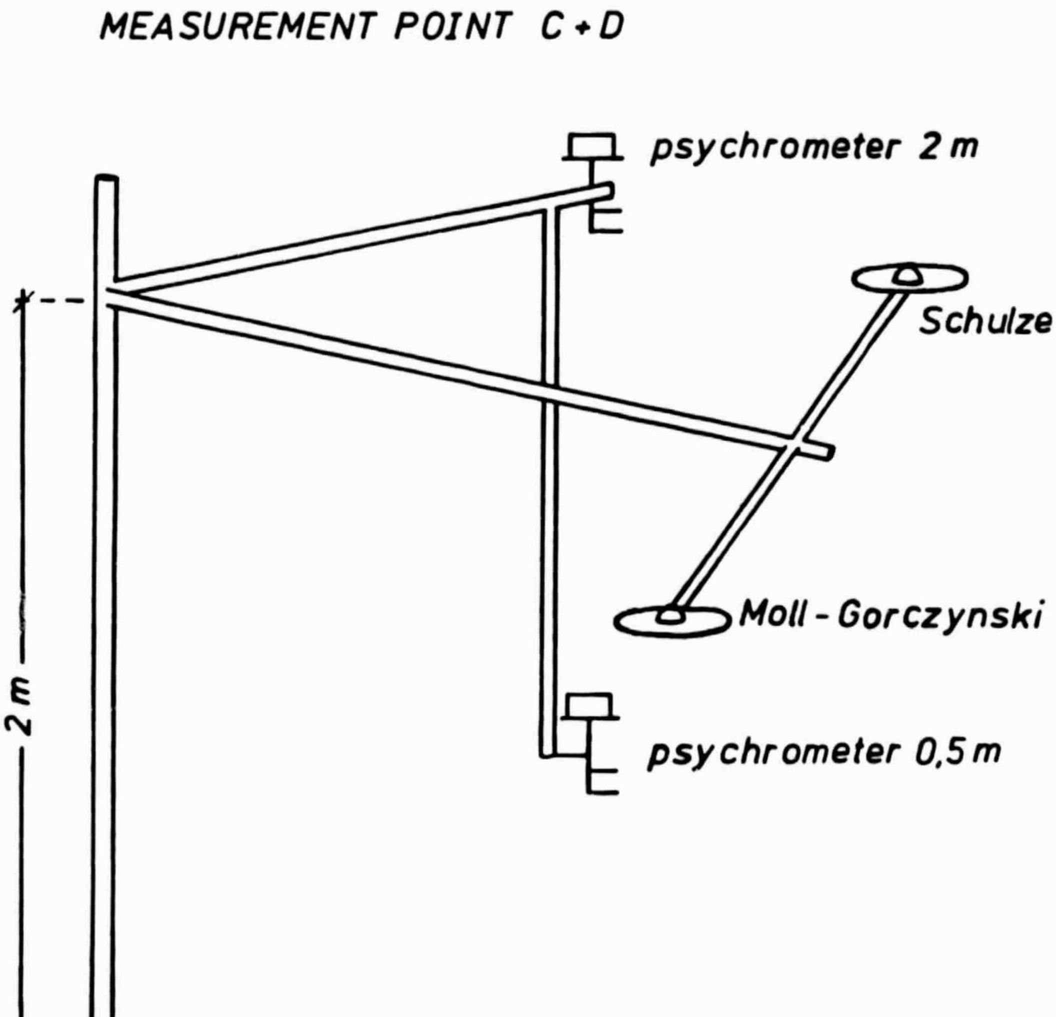


Fig. 16.6 Test Site C u. D
(2m rast) schematic

17. HCMM Calibrations at the Steinhuder Meer

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Calibration of HCMM at Lake Steinhude (Steinhuder Meer)

Following the Tellus Joint Measuring Campaign in Ruthe, HCMM calibration readings were collected on Lake Steinhude (Steinhuder Meer) for the satellite passages at noon and during the night of June 22 and 23, 1979. Because of unfavorable weather conditions and complete cloud cover during the night, both test runs hat to be carried out during the day passage of the satellite.

Location of Lake Steinhude

The Steinhuder Meer is the largest lake in Northwest Germany. The average altitude above sea level amounts 37.8 m, the coordinates being 52^{o} 28' N, 9^{o} 20' E. The lake covers normally an area of 29.1 km^2 and its volume is about 40.10^6 m^3. Its mean depth is 1.35 m. The greatest depth that was measured was 2.8 m. The lake and its environment are shown in Fig. 1 The shallow lake is situated approximately 25 km northwest of Hannover in a large depression extending from west to east between the Leine- and Weser-River.
The hydrographic conditions around the Steinhuder Meer show some special characteristics. In contrast to many other lakes no river flows through Lake Steinhude. The Meerbusch Creek is the only outlet westward into the Weser-River. Lake Steinhude receives its main recharge from ground water from areas in the south and the north.

Climate of Lake Steinhude

The climatic conditions of the area of Lake Steinhude are characterized by its location at the boundary between the

North German plain and the highlands in the south. The oceanic climate with its moderate summer and winter seasons dominating the northern plain is modified by continental influences in this area. The first ridges of the North German chain of low mountains produce a small-scale modification of the climate already at minor orographic differences through changes of luff- and leesides and by the change in altitude.

The climatic differences between highland and plain are cleary expressed in the amount of precipitation. The long-term yearly mean (1931-60) of the station Wilhelmstein (located on an island on Lake Steinhude) runs up to 592 mm. First of all this low value can be explained with the lee-effect of the Rehburger Mountains. A review about the distribution of the precipitation in the area around Lake Steinhude is given by the isohyeth chart published by the Office for Water Management of Hannover in 1975 (see Fig. 2).

Wind direction and speed are shown in Fig. 3. In general winds from westerly directions with an average wind speed of 5-6 m s^{-1} are dominating. The yearly mean temperature at Wilhelmstein (in Lake Steinhude) is 8.5^{o}C, the yearly mean amplitude being 16.5K. There are 100 days per year with fog formation on the lake and on the swamp lowland, which number exceeds comparable values of the environment.

The Test Run on June 22

Following the HCMM calibration of Price (1979), a test course over the lake was chosen in such a way that a net of temperature control points in a time as short as possible could be reached. The test course was carried out with a so-called peat boat driven by an outboard motor. Measurements were made between 12.24 GMT and 14.44 GMT. The location of the control points is indicated in Fig. 4 . A number of 22 control points had to be inspected. Water temperature in 10 cm depth as well as

dry-bulb and wet-bulb temperature 50 cm above the water surface were measured. Dry-bulb and wet-bulb temperatures were determined with the ventilated Asmann psychrometer. In addition cloud and weather observations were made.

The test course on June 23

This test course was also carried through with a boat driven by an outboard motor. This course started at 13.00 GMT and endet at 15.00 GMT. Measurements were made every two minutes. Water surface temperature, water temperature in 10 cm depth as well as dry-bulb and wet-bulb temperatures 50 cm above the water surface were determined. The control points are drawn in Fig. 4 . In addition the cloud and weather situation was observed.
Data pertaining to this test run are shown in Figs. 5a and 5b. They are tabulized in Table 1.

LEGEND TO FIGURES AND TABLES OF CHAPTER 17

Fig. 1	Map of Steinhuder Meer and its environment
Fig. 2	Map of mean precipitation at Steinhuder Meer
Fig. 3	Map of wind speed and wind direction at Steinhuder Meer
Fig. 4	Map of Steinhuder Meer indicating sequence of measure points (22 selected points)
Fig. 5a	Map of temperature datas (air temperature, water temperature, dewpoint) at 22 selected measure points
Fig. 5b	ditto with all measure points
Table 1	Data pertaining to the HCMM calibration experiment on June 23, 1978.

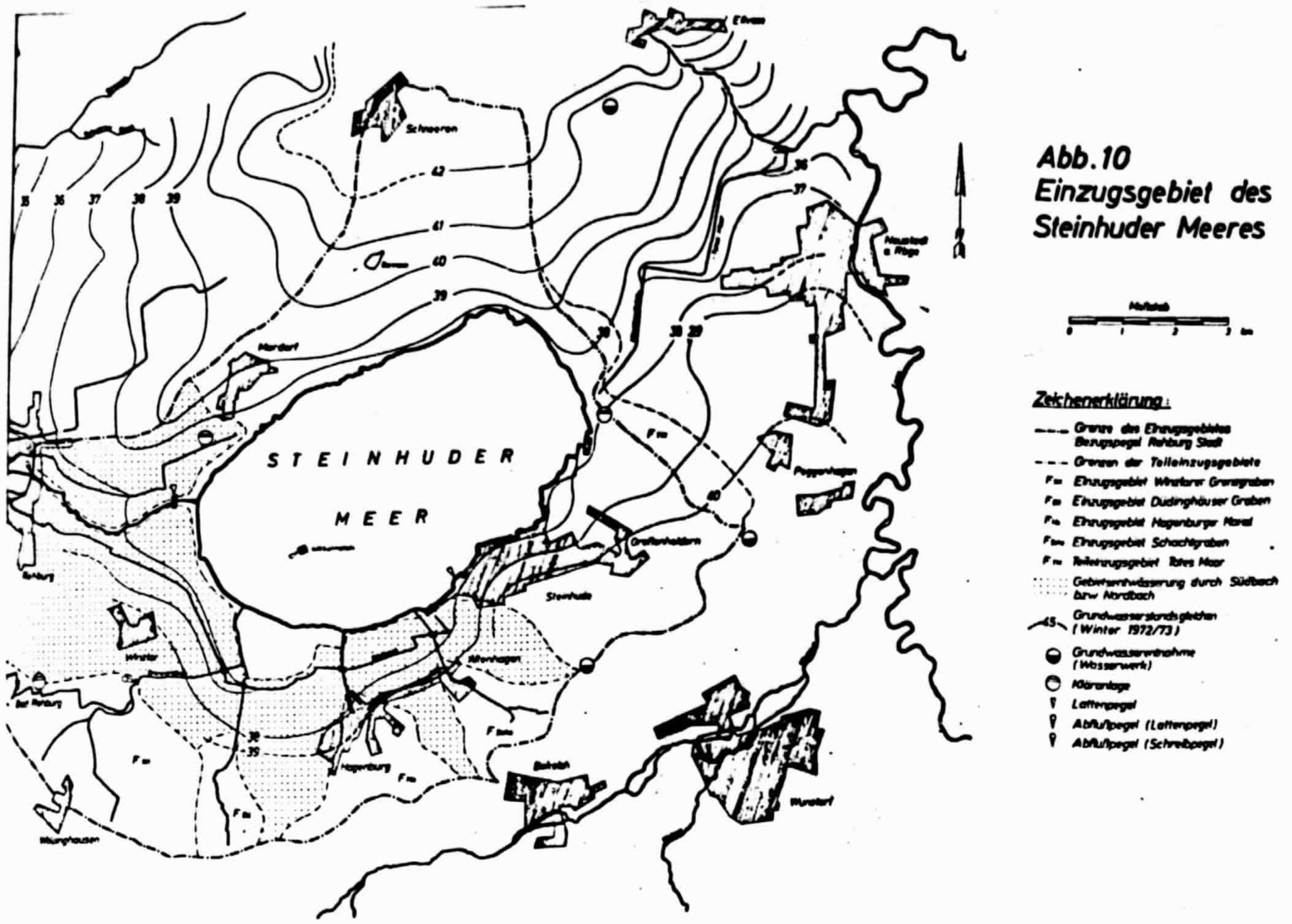


Fig. 17.1 Map of Steinhuder Meer and its environments

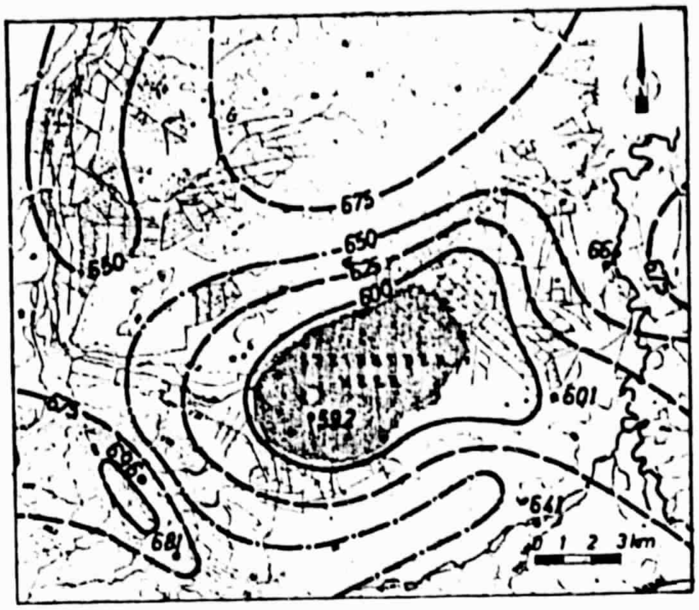


Fig. 17.2 Map of mean precipitation at Steinhuder Meer

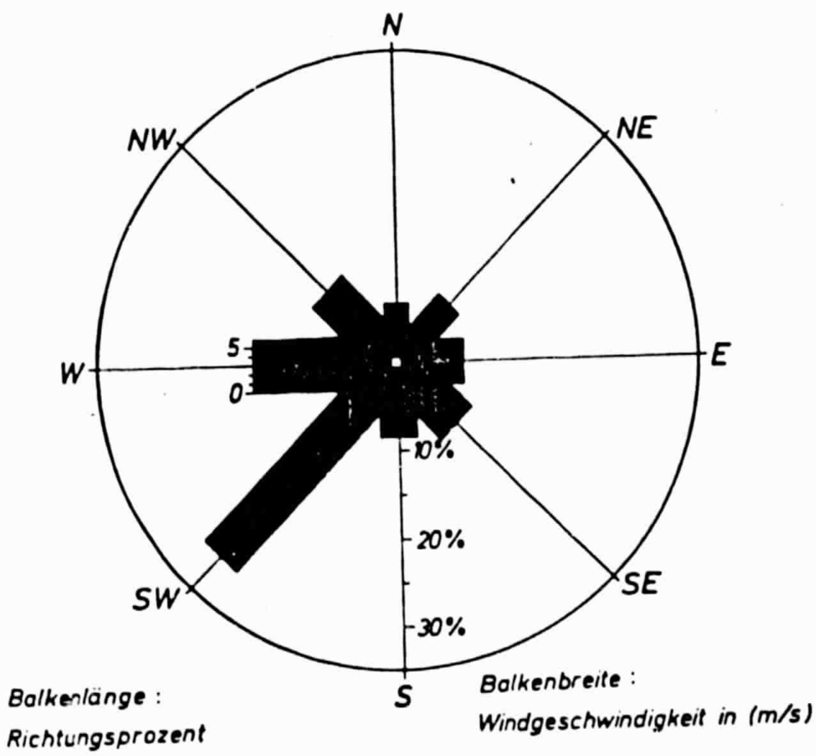
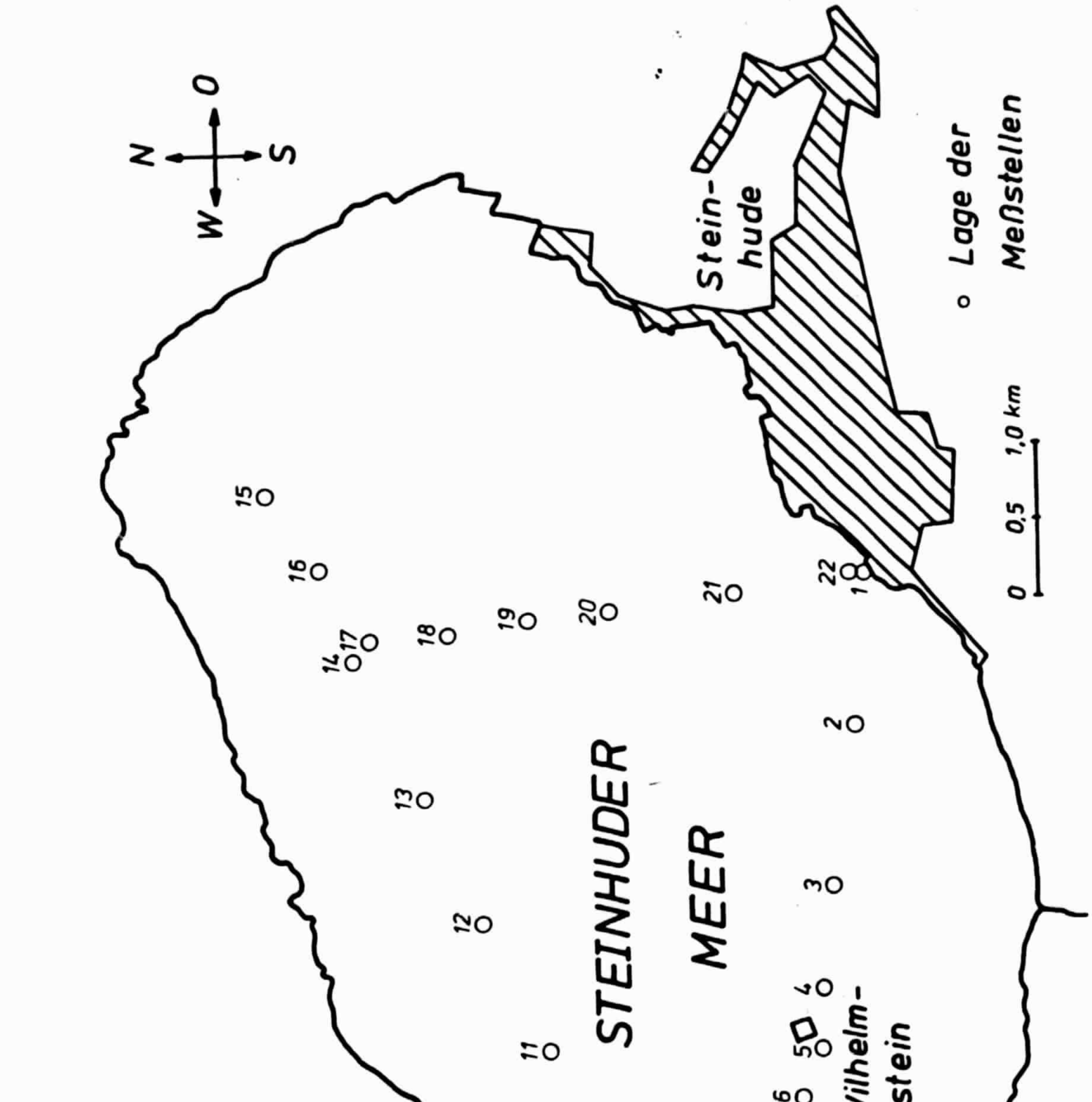


Fig. 17.3 Map of wind force and wind direction at Steinhude


N
W
O
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Mardorf
STEINHUDER
MEER
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12
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14
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16
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18
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20
21
22
0
0,5
1,0 km
Lage der
Meßstellen

Fig. 17.4

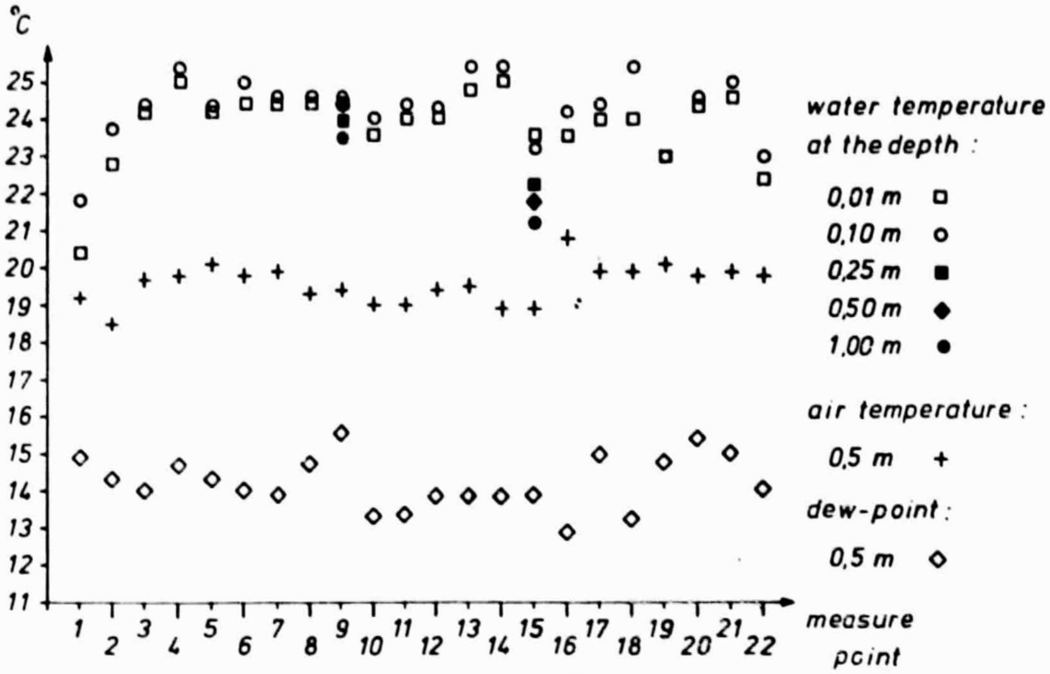

Fig.17.5a Water and air temperature measurements along the route marked in figure

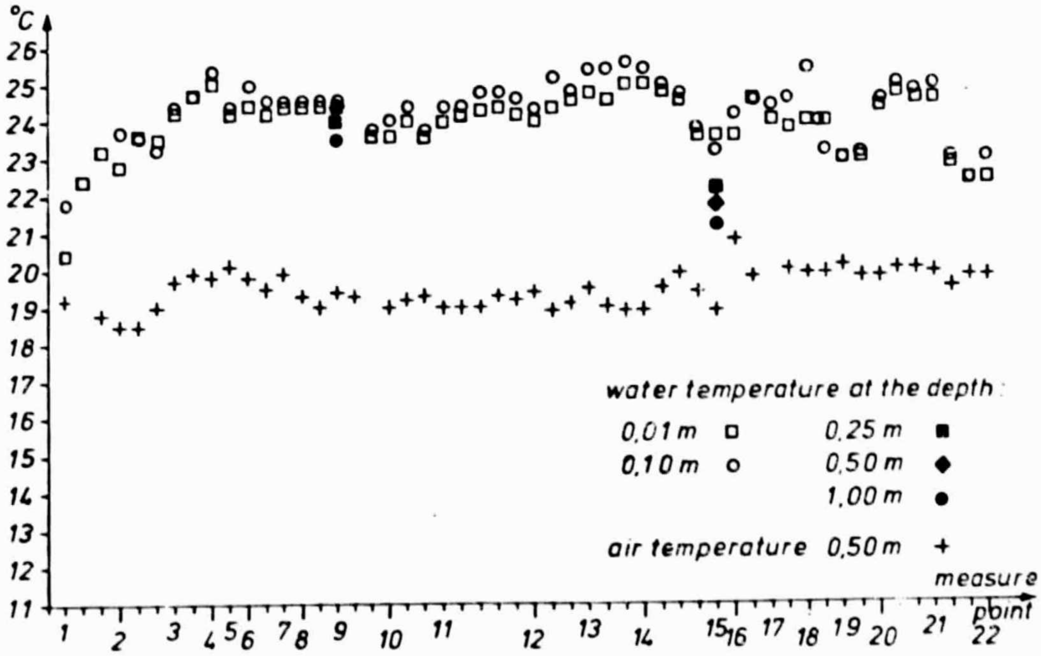

Fig. 17.5b Water and air temperature measurements along the route marked in figure

Tab. 17.1 Water and air temperature datas measured at Steinhuder Meer on June, 23rd 1979 at selected points

1	2	3	4	5	6	7	8	9
1	14.00	20.4	21.8	19.2	16.5	14.9	76	17.0
2	14.06	22.8	23.7	18.5	16.0	14.3	75	16.3
3	14.12	24.2	24.4	19.7	16.2	14.0	70	16.0
4	14.16	25.0	25.4	19.8	16.6	14.7	72	16.8
5	14.18	24.2	24.4	20.1	16.5	14.3	69	16.3
6	14.20	24.4	25.0	19.8	16.2	14.0	69	16.0
7	14.24	24.4	24.8	19.9	16.2	13.9	68	15.9
8	14.26	24.4	24.6	19.3	16.4	14.7	74	16.8
9	14.30	24.4	24.6	19.4	17.0	15.6	79	17.7
10	14.48	23.6	24.0	19.0	15.5	13.3	69	15.3
11	14.54	24.0	24.4	19.0	15.5	13.3	68	15.3
12	15.00	24.0	24.3	19.4	16.0	13.9	70	15.9
13	15.06	24.8	25.4	19.5	15,9	13.9	69	15.9
14	15.12	25.0	25.4	18.9	15.8	13.9	73	15.9
15	15.20	23.6	23.2	18.9	15.9	13.9	73	15.9
16	15.28	23.6	24.2	20.8	16.0	12.9	61	14.9
17	15.32	24.0	24.4	19.9	16.8	15.0	73	16.0
18	15.36	24.0	25.4	19.9	15.8	13.2	65	15.2
19	15.40	23.0	23.0	20.1	16.8	14.8	72	16.9
20	15.44	24.4	24.6	19.8	17.0	15.4	76	17.5
21	15.50	24.6	25.0	19.9	16.8	15.0	73	17.1
22	15.56	22.4	23.0	19.8	16.2	14.0	69	16.0

1 number of measure point
2 time (CET)
3 water temperature (1cm) in °C
4 water temperature (10cm) in °C
5 air temperature (50cm) in °C
6 wet bulb temperature (50 cm) in °C
7 dewpoint (50 cm) in °C
8 relative humidity in %
9 water vapor pressure in mbar